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THE EFFECT OF SOME TOXIC SOLUTIONS ON MITOSIS

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(WITH SEVEN TEXT FIGURES)

During the two decades just past there has arisen a considerable body of literature from the researches which have been made upon the physiology of the cell under the influence of various external conditions. The effect of certain stimuli on the growth and form of the organism and the modifications in the normal processes of cell and nuclear division induced thereby have been made the basis of numerous generalizations with respect to cellular activities.

Owing to its bearing upon questions of general and practical interest, the action of toxic substances on the growth of plants has been widely investigated. Notwithstanding this fact, our knowledge of the effect of such substances on cellular development in phanerogams is far from extensive, and the nature of toxicity itself yet lacks a satisfactory explanation. What may be called the modern epoch of the toxicity studies began with the researches of KAHLENBERG and TRUE (**10**), in which the action of chemically equivalent solutions of substances experimented with were for the first time compared.

According to the accounts of a number of writers, various departures from the normal course of nuclear and cell division have been caused experimentally by the action of solutions of various chemical constitution. The technic of this type of investigation was first developed by GERASSIMOW in the study of the cells of thallophytes, and later adapted to the study of higher forms.

Numerous investigators have studied the action of ether, chloroform, chloral hydrate, potassium nitrate, phenol, benzol, and copper

sulfate upon cell processes in certain plants, including Spirogyra, Tradescantia, Phaseolus, Lupinus, Vicia, Pisum, Allium, and Larix. The published accounts of these studies show a general agreement as to the production of certain abnormalities in cell and nuclear development. However, as to the occurrence of amitosis, binucleate cells, fusion nuclei with double the normal number of chromosomes and a heterotypic reducing division in the same, opinions are very conflicting.

GERASSIMOW (**8, 9**), NATHANSON (**16, 17**), PFEFFER (**24**), and WASIELEWSKI (**30**) found amitotic division of nuclei, but WISSELINGH (**32, 33**), NEMEC (**22**), ANDREWS (**2**), and WOYCICKI (**34**) saw no cases of amitosis.

Binucleate cells were observed by GERASSIMOW (**8, 9**), NATHANSON (**16, 17**), PFEFFER (**24**), NEMEC (**18, 20, 21, 22, 23**), BLAZEK (**3**), WASIELEWSKI (**30**), WOYCICKI (**34**), and STRASBURGER (**29**), but they were not found by WISSELINGH (**31**), ANDREWS (**2**), and KARPOFF (**11**).

Fusion nuclei were reported by GERASSIMOW (**8, 9**), NEMEC (**20, 21, 22, 23**), who found also double the normal number of chromosomes, and by STRASBURGER (**29**), but not by the other authors mentioned. The disappearance of the nuclei with the double chromosome number was explained by NEMEC (**22**) as due to a reduction division, in which he is followed by WOYCICKI (**34**). This conclusion is severely criticized by STRASBURGER (**29**) and by LAIBACH (**12**).

From this brief statement of the conflicting opinions advanced in some of the more important papers dealing with the direct effect of various chemical substances upon nuclear and cell division, it is evident that a much wider range of observation and experiment is required before conclusive generalizations can be drawn or the discordant results of the various investigators be brought into harmony. Moreover, in the higher plants the rate and the amount of growth in the seedling stages have been used almost entirely in the measure of the toxic effect, or when such was not the case some microscopic factor has been employed. Apparently there has been little detailed comparative study of the cell and nuclear activities in the higher plants during the course of treatment with an extended series of dilutions of a toxic agent.

The present investigation was carried out in order to observe the process of nuclear and cell division under certain definite conditions of physiological experiment with a series of toxic substances.

Materials and methods

In this study young seedlings of *Vicia Faba* were used, as they have furnished material for many similar investigations on the physiology of the cell and are well known as suitable material for the study of cellular activities. Uniform series of seedlings selected for the comparative tests were taken from the thoroughly washed sphagnum in which they had germinated, and suspended on glass rods in such a manner that the radicle for about 20^{mm} of its length was immersed in the solution. New nonsol glass beakers of 300^{cc} capacity were used, and a careful distinction was maintained throughout the experiments between those used for the controls and those used for the toxic solutions. This precaution was taken in order to avoid the possibility of the controls being injured by the residuum of copper which, as pointed out by NÄGELI (**15**), is taken up by the glass and may be given off later to contained solutions in quantity sufficient to affect seriously the radicles of plants grown therein.

The radicles were marked with India ink at a point 15^{mm} from the tip just before they were placed in the solution. When not under direct observation, the seedlings were kept in a dark cabinet in the laboratory at a fairly uniform temperature. The agents used were dilutions made from carefully prepared solutions of copper sulfate, strychnin sulfate, and phenol. The controls in the observations on growth rate were grown in distilled water. Either triple distilled water was used or the water was redistilled from glass just before use. Four seedlings were regularly used in each solution and their average growth was taken as the basis of comparison. Except in a few cases, when one or two tips were dead, four tips from each set of seedlings were prepared for microscopical examination.

In preparing the material for microscopical study, various modifications of Flemming's fluids were used in killing and fixing. Dehydration was followed by imbedding in 53° paraffin. The sections were cut $3–5\ \mu$ in thickness and stained on the slide with iron-alum-hematoxylin, safranin-gentian-violet, or the triple stain. A Zeiss

1.5^{mm} apochromatic objective and compensating oculars were used in studying the preparations.

This investigation was begun in 1904, at the suggestion of Dr. RODNEY H. TRUE, to whom I am indebted for constant advice and criticism. I am also under obligations to Dr. G. F. KLUGH, who was of great assistance with the seedling cultures.

Experimental

In all work with the radicles which involved measurement of growth, and in the preparation of material for killing and fixing, great precautions were taken to guard against the introduction of undesirable factors, such as loss of moisture, change in temperature, or shock in handling, which might interfere with the results sought.

THE EFFECT OF COPPER SULFATE SOLUTIONS ON GROWTH

Growth and cell activity in the root tips of *Vicia Faba* upon which copper sulfate solutions of various concentrations had acted continuously were the first subjects of study. Seedlings were placed in a series of solutions with a constant difference of dilution of $n/10{,}000$, in order to determine the concentrations in which the toxic effect would not be so strong as to prevent growth to some degree, after allowing time for recovery from the shock due to the change of medium and for partial acclimatization to the toxic substance. Table I shows the average growth of four seedlings in the various concentrations used, and also the growth made by the corresponding controls in distilled water. From the table it is apparent that, in the lower concentrations, the effect of a difference in dilution of $n/10{,}000$ is masked by the variability of the individual groups of seedlings, and in the higher dilutions this difference was increased many fold before changes in the growth rate were observed which could be reasonably ascribed to the action of the toxic solution. A comparison of the average growth per hour in the copper solution and in distilled water shows that there is a wide range of toxic effect between the concentrations $n/20{,}000$ and $n/500{,}000$, with a probable corresponding difference in cell activity, as shown by the slower rate of elongation in the stronger solutions.

TABLE I

COMPARATIVE GROWTH IN $CuSO_4$ AND DISTILLED WATER DURING THE FIRST DAY

RADICLES IN COPPER SULFATE SOLUTIONS				CONTROLS IN DISTILLED WATER	
Concentration	Time in solutions in hours	Total growth in mm	Average growth per hour in mm	Growth of corresponding control in mm	Average growth per hour in mm
n/20,000.....	16.5	0.5	....	8.7	0.52
n/30,000.....	19.5	0.5	....	5.0	0.25
n/40,000.....	19.5	1.8	0.09	12.8	0.65
	23.5	1.1	0.04	11.8	0.50
n/50,000.....	19.5	3.0	0.15	12.8	0.65
	20.0	3.7	0.18	7.8	0.39
	21.5	3.8	0.17	11.8	0.54
n/60,000.....	19.5	4.4	0.22	7.8	0.40
	21.5	1.8	0.07	10.2	0.47
n/70,000.....	19.0	8.0	0.42	12.1	0.63
	20.0	6.0	0.30	11.0	0.55
	20.0	5.7	0.28	13.0	0.65
n/80,000.....	18.5	4.5	0.24	11.3	0.61
	19.0	9.2	0.48	12.1	0.63
	20.0	5.9	0.29	13.0	0.65
n/90,000.....	18.5	5.1	0.26	11.3	0.61
	19.0	9.7	0.51	12.1	0.63
	20.0	5.4	0.27	13.0	0.65
n/100,000....	18.5	7.0	0.37	11.3	0.61
	19.0	11.2	0.58	12.1	0.63
	20.0	8.3	0.41	13.0	0.65
n/110,000....	18.5	7.0	0.37	11.3	0.61
	21.5	6.5	0.30	14.6	0.67
	24.0	8.5	0.35	14.3	0.59
n/120,000....	21.5	6.8	0.31	14.6	0.67
	24.0	9.5	0.39	14.3	0.59
n/130,000....	21.5	8.0	0.37	14.6	0.67
	24.0	12.3	0.51	14.3	0.59
n/140,000....	21.0	5.0	0.23	8.3	0.39
	24.0	11.8	0.49	16.0	0.66
n/150,000....	21.0	6.5	0.30	8.3	0.39
	22.0	13.5	0.61	16.5	0.75
n/160,000....	24.0	12.8	0.53	16.0	0.66
n/250,000....	19.0	11.5	0.60	14.2	0.74
	19.0	8.8	0.46	10.3	0.54

TABLE I—*Continued*

Radicles in copper sulfate solutions				Controls in distilled water	
Concentration	Time in solutions in hours	Total growth in mm	Average growth per hour in mm	Growth of corresponding control in mm	Average growth per hour in mm
n/275,000....	19.0	11.8	0.61	14.2	0.74
	19.0	11.0	0.57	10.3	0.54
	18.0	7.8	0.42	15.0	0.83
n/300,000....	19.0	11.2	0.58	14.2	0.74
	19.0	10.3	0.54	11.5	0.60
	19.0	14.0	0.71	10.3	0.54
	18.0	6.0	0.33	15.0	0.83
n/400,000....	19.0	10.0	0.52	11.5	0.60
	18.0	12.7	0.70	15.0	0.83
	24.0	14.8	0.61	15.8	0.65
n/500,000....	18.0	16.0	0.88	15.0	0.83
	24.0	13.7	0.57	15.8	0.65

Observations were next made on the growth rate to ascertain whether the retardation occasioned a gradually increasing lag in rate of elongation, or an abrupt termination of growth due perhaps to the sudden failure of vitality in the cell. Table II shows the average growth of several groups of four radicles, each selected from the various concentrations, and of the corresponding controls in distilled water. The several growth periods recorded for each concentration were consecutive.

With one exception, growth was in every case less in the copper sulfate solution than that made by the control in distilled water. In the higher concentrations growth was practically inhibited at the end of a twenty-four hour period. Passing down the series the growth is seen to be gradually diminished after the first twenty-four hours. A similar reduction in growth rate is apparent in the controls, though in a degree much less marked.

The observations summarized in tables I and II indicated that the series of concentrations selected would afford material showing strong toxic action resulting ultimately in death (*n*/20,000 to *n*/50,000), as well as the more prolonged and gradual though no less fatal effect of higher dilutions.

TABLE II

AVERAGE GROWTH IN COPPER SULFATE SOLUTIONS AND DISTILLED WATER*

COPPER SULFATE SOLUTION			DISTILLED WATER
Concentration	Time in solution in hours	Growth in mm	Growth of corresponding control in mm
n/50,000	21.5	2.3	10.2
	24.5	0.0	8.0
	49.0	0.0	11.6
n/90,000	20.0	4.5	11.0
	24.0	1.2	12.3
n/110,000	18.5	7.0	11.3
	25.0	2.0	11.7
	22.5	0.5	9.7
n/150,000	21.0	6.5	8.3
	22.0	4.0	10.2
	24.0	0.7	10.2
n/250,000	19.0	11.5	14.2
	24.0	9.2	14.0
	24.0	3.7	11.2
n/300,000	19.0	11.2	14.2
	24.0	5.7	14.0
	24.0	0.5	11.2
n/400,000	18.0	12.7	15.0
	24.0	10.5	13.0
	24.0	4.2	10.0
n/500,000	18.0	16.0	15.0
	24.0	15.2	13.0
	24.0	7.2	10.0
n/500,000	24.0	13.7	17.2
	24.0	7.5	14.7
	24.0	1.5	2.7
	24.0	0.5	3.0

*The intervals under each concentration represent consecutive periods of exposure for a single group of seedlings. The sum of these intervals will give the total time in the solution.

THE EFFECT OF DILUTE SOLUTIONS OF COPPER SULFATE ON MITOSIS

The material discussed in this section was selected from cultures in various concentrations of copper sulfate, and the root tips chosen for study, together with the corresponding control in distilled water, were fixed in the manner noted above at intervals of approximately twenty-four hours. Some preparations were made at other intervals in order to increase the range of observations.

In root tips fixed after an exposure of one hour to $n/20{,}000$, mitosis was arrested; after 16 hours the root tips were dead. After 20 hours in $n/30{,}000$ there were no mitoses, and the cells of the dermatogen, outer periblem, and meristem were dead and disintegrating. The nuclei of the cells not disorganized were of normal size and occasionally contained two nucleoli.

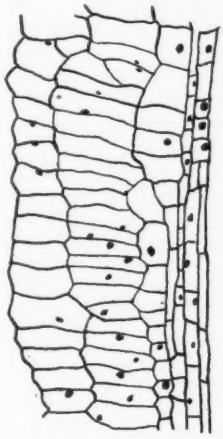
After exposure for 40 hours to $n/40{,}000$ there were only rare mitoses. The outer cell layers were plasmolyzed, the mid-plerome cells were vacuolate, and the persistent nuclei shriveled. The nuclei of the larger number of the other cells of the plerome were resting and very frequently contained two nucleoli. The apex of the tip was dead, but some development in the plerome region was evidenced by the thickened walls of the cells destined to form the fibrovascular bundle. These thickened cells extended down to within 2^{mm} of the end of the radicle. At 3^{mm} from the apex of the tip there was an area of hypertrophied periblem cells (*fig. 1*) which had developed to several times the normal size, producing distortion of the radicle and giving it a swollen edematous appearance on one side. Since the nuclei in these cells were disorganized, a corresponding increase in size could not be determined.

In tips exposed for 6 hours to $n/50{,}000$ there were a few division figures. An exposure of 20 hours to this concentration killed all the cells in the meristem region. Many of the middle periblem cells were greatly enlarged, and in the others practically all nuclei were in the resting stage and were rich in chromatin. Cells with two nucleoli were very common in the plerome region, where also a few cells were observed containing three nucleoli. In general appearance the plerome cells resembled those shown in *fig. 2b*. After 44 hours practically all the cells were dead and disintegrating.

An exposure of 20 hours to $n/70{,}000$ killed the outer layers of cells, but in the inner periblem normal chromatic figures were present, and as in the preceding cases the achromatic figures were obscure. At the end of 46 hours large vacuoles appeared in the cytoplasm of many cells, and frequently so crowded upon the nucleus that it was driven to one side of the cell. Nearly all of these cells were enlarged in size and irregular in outline. In the inner periblem practically all stages of the chromatic figure occurred, although very few cells

contained other than resting nuclei. After 69 hours' exposure to this concentration the older periblem cells were still more enlarged and the outer ones were disintegrating. A few of the inner periblem cells showed division stages, none of which were later than early anaphase.

The cells of the root tips treated with $n/190{,}000$ for 44 hours differed little from those in $n/70{,}000$ for the same length of time.



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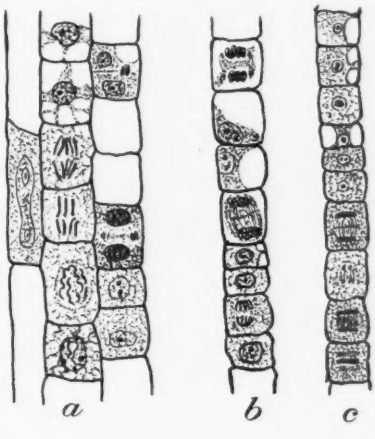

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FIG. 1. Proliferated cells of root tip grown in dilute copper sulfate solution.—FIG. 2. *a*, cells of root tip of *Vicia Faba* after 96 hours in distilled water; *b*, the same after 46 hours; *c*, *Lupinus albus* 69 hours in distilled water.

After 72 hours there was no division, and the periblem cells were frequently enlarged.

In the outer periblem of the material treated with $n/100{,}000$ for 43 hours, a few cells occurred containing division figures. In the inner periblem many nuclei were in the spireme stage and the meristem area was especially active. In these inner cells the achromatic figure appeared to be normally developed, but in the outer layers the cells were more or less vacuolized, and the spindle fibers were degenerating. In 93 hours this condition had spread to all the cells.

Approximately similar conditions occurred in the radicles treated in the concentrations $n/140{,}000$ and $n/150{,}000$. In 93 hours prac-

tically all cells were dead, the outer layers being also disorganized. However, in the case of the material in $n/150{,}000$ for 93 hours, in the periblem cells about 3^{mm} from the apex of the root tip a few mitotic figures occurred. In the corresponding controls in distilled water, chromatic figures were frequent even in the outer periblem cells, but many abnormalities occurred in the achromatic figures and cytoplasm (*fig. 2b*). Nuclear division occurred here and there in the inner periblem of tips which had been 93 hours in a $n/160{,}000$ solution, but the outer periblem was dead and disorganized. The division figures did not differ from those in the controls, and the nuclei in the resting stage were normal in appearance. In tips exposed for 68 hours to the action of $n/300{,}000$, $n/400{,}000$, and $n/500{,}000$ solutions, division was frequent in all parts of the active tissue and did not differ essentially from that in the corresponding controls. However, the outer cell layers of the tips in the copper solutions were less active, and the total number of mitoses was smaller than in the controls. The cytoplasm of many cells contained vacuoles of variable size, some being so large as to crowd heavily upon the nucleus. The same phenomenon occurred, though less frequently, in the controls.

DEMOOR (**7**), who studied the effect of chloroform on the cell protoplasm, observed therein a marked vacuolization which he regarded as the direct result of the action of this reagent. Also NEMEC (**18**) found that chloroform and potassium nitrate produced vacuoles in both chromosomes and cytoplasm of *Vicia Faba*, and BLAZEK (**3**) states that benzol vapor caused the vacuoles of the cytoplasm so to increase in size that they caused deformation of the nuclei. However, since vacuoles, similar to those observed in the course of these experiments with copper sulfate, occurred also in the controls in distilled water, it would appear to follow that this phenomenon is not necessarily due to a narcotic or poisonous action, but may result from an alteration in the concentration of the cell fluids.

Before the examination of the toxicated material had proceeded very far, it became evident that the conditions of mitosis in the controls grown in distilled water were far from normal. The entire series of controls was thereupon reexamined, and a progressive degeneration demonstrated therein closely resembling that in the cells treated with

the copper solutions. After 7 hours in distilled water there was little division in the periblem, the figure in a few cells being in early prophase. Division was active in the plerome. After 22 hours division had ceased in the outer layers, but still occurred normally in the inner tissues. In 46 hours the radicles were curved, numerous cells were dead, large vacuoles occurred in the cytoplasm, and in many cells the achromatic figure was degenerating (*fig. 2b*). The general condition after 96 hours is illustrated in *fig. 2a*. Particularly striking are the large nuclei, the cytoplasmic vacuoles, and the interrupted cell plate seen in one of the upper cells of the figure. *Fig. 2c* represents a group of cells from a radicle of *Lupinus albus* after 46 hours' exposure to distilled water, and is inserted here for the purpose of comparison. In these cells also vacuoles occurred in the cytoplasm, and there was some degeneration of cytoplasmic structure.

It appears that the distilled water exerted practically the same effect on mitosis as was produced by the dilute copper sulfate solutions, but only after a more prolonged exposure.

THE EFFECT OF MORE CONCENTRATED SOLUTIONS OF COPPER SULFATE

In planning the experiments with stronger solutions of copper sulfate, some paragraphs from NEMEC's "Ueber ungeschlechtliche Kernverschmelzungen" (**21**) were held in mind. In this paper NEMEC describes the production of binucleate cells and other abnormalities by placing the radicles of *Vicia Faba* for thirty minutes in 1 per cent solution of copper sulfate and then transferring them to moist sawdust for seven hours. NEMEC's experiment seemed to indicate that *Vicia Faba* was remarkably resistant to the action of copper solutions, indeed to a far greater degree than in *Lupinus albus*, in which, as was learned through access to some unpublished notes of Dr. R. H. TRUE, some growth can occur after an exposure of eight minutes' duration to a $n/16$ solution of copper sulfate. A test quickly showed that thirty minutes' exposure to a 1 per cent copper sulfate solution (approximately $n/12$) was fatal to the material being used in these experiments. A series of preliminary experiments was carried out, therefore, to establish approximately the time limit

which would just permit growth in $n/4$ and $n/12$ solutions as boundary concentrations, with results indicating that a slight amount of growth would follow exposure to a $n/4$ solution for three minutes, and that seven minutes' exposure to the $n/12$ solution, while permitting some growth, was not far from the point of killing.

For the experimental work the solution $n/12$ was chiefly relied upon as being best suited to give a sharp toxic effect, without endangering the loss of the material through death. The radicles were exposed to this solution for periods of three and seven minutes, respectively, were then rinsed quickly in distilled water, and at once transferred to the medium in which they were kept until the time for killing and fixing. Another dilution and longer interval of exposure were also employed to furnish a broader basis for observation.

In order to have at hand for constant comparison material grown under parallel conditions with the toxicated radicles, except for the treatment with the copper sulfate solutions, a uniform lot of seedlings was taken from the germinating chamber, selected to approximately the same size, and divided into six groups which were then prepared as follows: (*a*) one group in moist sphagnum; (*b*) one in distilled water; (*c*) one in $n/12$ copper sulfate three minutes, then sphagnum; (*d*) one in $n/12$ copper sulfate three minutes, then distilled water; (*e*) one in $n/12$ copper sulfate seven minutes, then sphagnum; (*f*) one in $n/320$ copper sulfate ten minutes, then distilled water.

Four root tips were fixed from each series at intervals of 3, 7, 22, and 30 hours. Sections of the tips from the first two series, designated as the controls in the following pages, were compared at every stage with the sections studied in the remaining series.

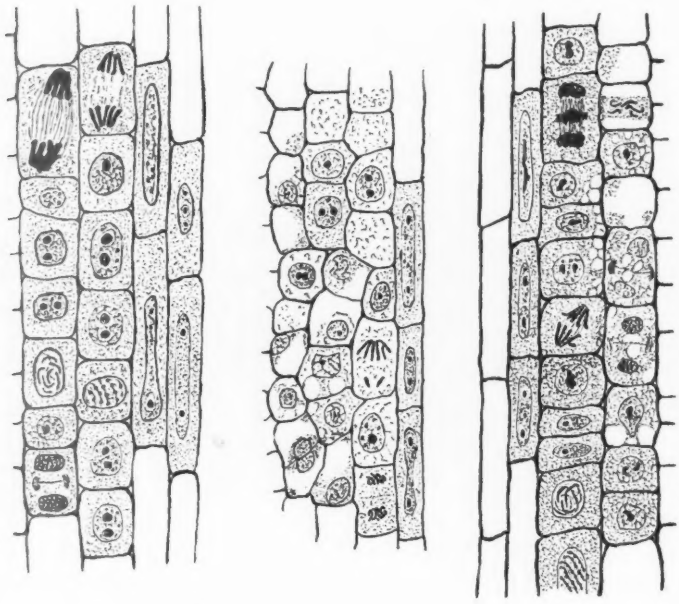
The cell growth and nuclear division observed in the controls placed in sphagnum were considered as normal, since good preparations were secured showing abundant mitoses, all of which conformed to the type generally reported as occurring in vegetative tissues of *Vicia Faba* (*fig. 6*). Departures from the normal cell division were observed in the controls grown in distilled water similar to those observed in the controls paralleling the cultures in dilute copper sulfate solutions (*figs. 2a, 2b*). Since the radicles in the copper sulfate solutions were manipulated under conditions identical with those obtaining in the controls, except for the exposure to the toxic solution,

marked discrepancies in nuclear behavior, it was believed, could safely be regarded as a result of toxic action.

Root tips which were exposed to $n/12$ copper sulfate solution for three minutes and then transferred to distilled water for three hours showed the effect of strong toxic action in the peripheral cell layers. Here the cells were dead, but in the inner periblem occasional nuclei were in division, but frequently the cell plate had failed to form (*fig. 3*). In the majority of the uninjured cells the nuclei were in the typical resting stage. In no case did nuclei which were in the spireme stage show the hyaline polar caps, frequently figured as characteristic of the development of the normal achromatic figure in *Vicia Faba*, and occurring in the controls grown in sphagnum in these experiments (*fig. 6*). The nucleoli were usually large and frequently occupied a clear area surrounded by the linin network, as seen in *fig. 3*. Many nuclei contained two large nucleoli, each lying within a distinct clear area. In the degenerating nuclei of the injured cells the persistent nucleolus was generally of very large size, and the form of the nucleus was usually outlined only by the linin network, all chromatic substances other than the nucleolus having lost their usual staining properties. In some cells the cytoplasm showed modifications apparently due to the action of the copper sulfate, although these were usually not sharply defined, but in some cases numerous large vacuoles occurred distributed through the cytoplasm, in others huge vacuoles had formed at the sides of the nucleolus, presenting much the appearance of the older cells in which large sap cavities had formed.

In root tips which had been exposed for three minutes to $n/12$ copper sulfate solution and then placed in water for seven hours, the cells presented much the same general appearance as those examined at the end of the three-hour period. The greater part of the nuclei were in the resting stage, though a few cells of the inner periblem showed spiremes forming. Occasional nuclei were farther advanced in division, but no stage later than middle anaphase was seen. In the distribution of the chromosomes, and in their manner of passing from the nuclear plate, no deviation from the typical process occurring in the controls in sphagnum was observed. After 22 hours a decided change in the appearance of the cells of the root

tip was apparent. The dermatogen had exfoliated and the periblem cells, having lost their normal rectangular form, were irregularly rounded. All early stages of mitosis were present, and the development of the chromosomes had proceeded normally. All stages of



3 4 5

FIG. 3. *Vicia Faba* three minutes in *n*/12 copper sulfate, then three hours in distilled water.—FIG. 4. *Vicia Faba* three minutes in *n*/12 copper sulfate, then twenty hours in distilled water.—FIG. 5. *Vicia Faba* seven minutes in *n*/12 copper sulfate, then three hours in distilled water.

mitosis up to the formation of the cell plate occurred, but with frequent degeneration of the spindle fibers (*fig. 4*). The newly formed division walls separating certain cells were very thin and indistinct, and the appearance presented on first examination suggested the binucleate cells described by NEMEC (**22**) and others. These division walls were usually asymmetric with the other cell walls. In

the root tips examined after 30 hours, division still occurred in the periblem cells. The chromatic figure was regularly found, but only in the inmost layers of cells was the spindle unaffected. The nuclear plate had formed in the central spindle region of most cells, but usually failed to reach the walls.

In the root tips placed in distilled water for three hours after seven minutes' exposure to $n/12$ copper sulfate, very few mitoses occurred in the periblem cells, but in these the chromatic figure presented a normal appearance. The cytoplasm of all the outer periblem cells exhibited large vacuoles, some of which had enlarged sufficiently to drive the nucleus to one side of the cell, and in the inner periblem frequent cells developed unusual vacuoles. In some cells in late anaphase vacuoles occurred between the cell plate and the daughter nuclei (*fig. 5*), a condition which occurred also in the distilled water controls, but division did not proceed farther in the copper solution. At one side of some cells the plate, failing to reach the lateral wall, ended in a fibrous plasma mass about half-way between the axis of the spindle and the wall of the cell. In the cells at the apex of the root tip occasional nuclei were in early prophase, anaphase was frequent, and a few nuclei were at telophase. In the latter stage the cell plate had formed in the normal manner, but in practically all the nuclei at anaphase no trace of cell plate appeared. In some cells the spindle fibers were only faintly visible, in others a perceptible thickening of the fibers had occurred in the equator of the spindle, but no figure showed the line of granules characteristic of cell plate formation. In the resting nuclei, as usual, there occurred one or two large nucleoli. These were rarely circular as viewed in optical section, but were amœboid in form.

In radicles placed for ten minutes in $n/320$ copper sulfate, then transferred to distilled water for three hours, the dermatogen cells were dead and many of the outer periblem cells lacked nuclei. The nuclei present were in the resting stage. Numerous mitoses occurred in the cells of the plerome and inner periblem, but the larger number showed a tendency toward degeneration in the spindle fibers. After seven hours the general appearance of the cells was much the same, but there were very few mitoses. After 22 and 30 hours, respectively, no division figures occurred in the outer cell layers, but a few cells

in the periblem and inner plerome still showed normal chromatic figures; some nuclei were in the spireme stage, although the majority were resting; cellular activity, as expressed in division, had practically ceased.

A comparative estimate of the proportion of cells in course of division in each of the several experiments did not show that any concentration used had stimulated division; on the contrary, the retarding influences, particularly in the more concentrated solutions, were very pronounced. The first apparent effect of the toxic solution was arrest of nuclear division through inhibition of the activities of the achromatic figure. In the early division stages this was soon followed by degeneration of the spindle fibers. In the later stages of division the failure of cell plate formation was characteristic. These phenomena were accompanied or followed by an increase in the number and size of the vacuoles in the cytoplasm. The death of the cell evidently occurred shortly after this condition was reached.

It seems probable that the toxic solution penetrates somewhat slowly to the inner cell layers, since under its influence the outer layers of cells are killed, while in the inner regions not yet visibly affected, normal development continues.

There was no satisfactory evidence of the occurrence of amitosis. Double nucleoli occurred as frequently in the cells of the controls as in those treated with the copper solutions, a result which, so far as these experiments have extended, directly controverts the statement of WASIELEWSKI (**30**) that "das erste Kennzeichen, dass ein Kern sich zur amitotischen Theilung anschickt, besteht in einer Verdoppelung des Nucleolus."

The copper solutions did not cause abnormalities in the development of the chromatic figure. There was no doubling of the normal number of chromosomes. Occasionally two daughter chromosomes remained attached by their ends for some time after the others had left the nuclear plate, apparently forming an attachment between the daughter chromosome groups. However, this irregularity was also observed in the controls. NEMEC (**21**) states that treatment with 1 per cent copper sulfate solution produced binucleate cells in root tips of *Vicia Faba*. After 17 hours' sojourn under normal conditions binucleate cells no longer appeared, and he concluded, therefore, that

the nuclei in the binucleate cells had fused. The experiments here described furnish no support to this theory of nuclear fusion, since no cells were observed that contained more than one nucleus. Occasionally, through failure of the nuclear plate, cells appeared to contain two nuclei, but these daughter nuclei were never fully reconstituted, and the cells were degenerating.

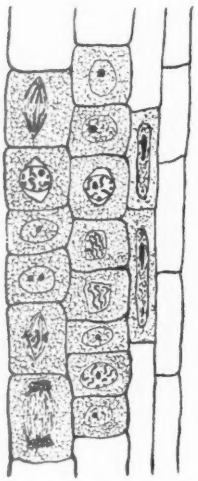
The stronger copper solutions inhibited mitosis, disorganized the spindle fibers or interrupted their formation, arrested the development of the cell plate, and produced large vacuoles in the cytoplasm. The same effects were produced in the controls in distilled water, though to a less marked degree, and after a longer period of exposure. There were no abnormalities in the controls grown in sphagnum.

THE ACTION OF PHENOL

In studying the action of phenol a normal solution was prepared, and various dilutions were made therefrom in the course of the experiment. Controls were grown in moist sphagnum and in distilled water. The continuous action of phenol was observed in $n/94$ and $n/188$ solutions, respectively. Solutions of 10/94, 5/94, and 1/188 normal were allowed to act on radicles for 20 minutes, after which they were placed in distilled water and material killed and fixed therefrom at intervals of 4, 21, and 45 hours. Material from the controls received parallel preparation. In the microscopical examination of the toxicated root tips no unusual structure or condition was considered as due to the action of the phenol until careful search had shown that its equivalent did not exist in the controls.

The continuous action of a $n/94$ solution of phenol for four hours seriously injured both the cytoplasm, which showed numerous small vacuoles, and the achromatic portion of the nucleus. Numerous spireme nuclei were observed, many of which were much enlarged and irregularly distended apparently by a great increase in the amount of nuclear sap within them. Occasionally these enlarged spireme nuclei were laterally indented by the formation of a dense plasma mass at one side (*fig. 7a*). These nuclei very much resembled those described by NEMEC (**22**) as formed under the influence of chloral, of which he says: "In einiger Zellen giebt es mehr oder weniger tief eingeschnürte Kerne." At this point the resemblance ceases, and no support can

be given to NEMEC's further statement that "diese Zellen können Scheidewandanlage besitzen." Since no other unusual forms were observed in either cell or nucleus, these are regarded as nuclei in the course of disorganization. In the older as well as in the younger portions of the root tip nuclear figures occurred which usually showed



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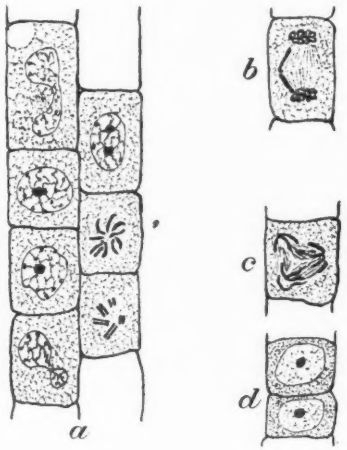

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FIG. 6. Normal cells from a root tip of *Vicia Faba* grown in moist sphagnum.—FIG. 7. *a*, *Vicia Faba* in *n*/94 phenol four hours; *b*, retarded separation to chromosomes; *c*, multipolar spindle; *d*, enlarged nuclear areas.

the achromatic spindle or its remnants. However, no division stage later than very early anaphase was present. The chromosomes in part of these figures had split longitudinally, in others no splitting occurred. In no case had the chromosomes left the nuclear plate. Evidently the movement of the daughter chromosomes from the nuclear plate to the poles of the spindle had here been inhibited by the action of the phenol upon the mantle fibers.

At the end of 21 hours the root tips had a dull white luster, and were evidently dead. Upon examination all the cells were found to be plasmolyzed.

The radicles which had been for four hours in $n/188$ phenol were next examined and all stages of mitosis found. The cytoplasm of the cells of the outer layers exhibited a coarsely netted structure due to the formation of numerous small vacuoles. Occasional spireme nuclei were unduly enlarged, and in a very few cases the nuclei were constricted in one diameter, apparently by the development of a plasma mass as previously noted. The early stages of the spindle were very obscure, but during anaphase the fibers became quite distinct. A few cases of late anaphase occurred in which occasional chromosomes had not left the nuclear plate, but remained at one side of the spindle in line with the row of granules marking the early stages of cell plate formation (*fig. 7b*). A similar occurrence was observed by BLAZEK (**3**) in the cells of root tips of Pisum treated with benzol, and in *Vicia Faba* also by SCHRAMMEN (**27**), who says: "Eine nicht seltene Erscheinung bei der plötzlichen Einwirkung von hohen Temperaturen ist das Nichterfassen von Chromosomen durch die Spindelfasern und das Zurückbleiben einzelner Chromosomen bei dem raschen Transport zu den Spindelpolen." In a few cases the chromosomes at one pole of a spindle had diverged and formed two groups, to each of which a portion of the spindle extended (*fig. 7c*). SABLINE (**26**), who produced similar phenomena by the use of sulfate of quinine, says, "Sur quelques figures multipolaires on peut voir deux et quelquefois trois fuseaux." In the material treated with phenol, however, multipolar spindles occur so rarely that there seems to be no good ground for assuming that they are produced by the action of this reagent.

After an interval of 21 hours in $n/188$ phenol there were no mitoses. The nuclei were all in the resting stage and for the most part contained but a single nucleolus. General disorganization of the cells of the root tips had begun.

Tips of radicles were treated for 20 minutes with $10/94$ normal phenol and then transferred to distilled water for four hours. At the end of this time all nuclear activity had ceased. In most cases the nucleus was enlarged, and in the field of the microscope appeared as a light area against the darker background of the cytoplasm of the cell (*fig. 7d*). The chromatin had almost entirely disappeared from the nuclear network. Very prominent in the nucleus appeared

one or two large and deeply staining nucleoli. After 24 hours under similar conditions there was little change in the appearance of the cells. Plasmolysis in occasional cells and the collapsed walls of the outer cell layer indicated that disorganization had begun.

Next 5/94 normal phenol was allowed to act for 20 minutes on root tips, which were then transferred to distilled water for four hours. There were no mitoses. In certain cells of the inner periblem and in some plerome cells elongating to form procambium, large vacuoles occurred, while many enlarged nuclei had partially collapsed. The general condition of the cells resembled very closely that obtaining after the exposure for four hours to the 10/94 normal solution. After 21 hours the root tips had made no further growth and were evidently dead. Disorganization of the cell structures, however, had not progressed so far as in the case of the material with 10/94 normal for the same time. Here again the nuclear area was enlarged, though very regular in form, and had a lighter hue than the surrounding cytoplasm. In the radicles treated for 20 minutes in the other dilutions employed, continuous growth occurred and development was apparently normal. After 20 minutes' treatment with $n/94$ and $n/188$ phenol, respectively, and then with distilled water for 45 hours, the root tips were fresh and crisp and had elongated at approximately the same rate as the distilled water controls. Mitoses were frequent, and the more active regions of the cytoplasm, particularly the achromatic figure, showed no injury as a result of the action of the phenol.

Phenol in common with most antiseptics is a marked protoplasmic poison. Certain results of its action were especially apparent in the cells of the root tips treated continuously with this reagent. The achromatic figure of the division nucleus in early anaphase was seriously injured and mitosis inhibited. The nuclear plate stage was apparently unusually sensitive to the action of the phenol, since the spindle fibers as a rule failed to function normally in drawing apart the daughter chromosomes. As previously noted, the development of small vacuoles in the cytoplasm appears to be a characteristic effect produced by the phenol. There was no amitotic division and no tendency toward the production of binucleate cells was observed.

In the material treated for 20 minutes with the stronger solutions and then with distilled water, the most striking modification was the

enlarged nuclear area surrounded by cytoplasm of a darker hue. Here also the cytoplasm usually contained small vacuoles, but neither amitosis nor abnormal division figures occurred. The general course of events under the action of the phenol seems to be the progressive decline of the cell functions, beginning in the most active and labile regions of the cytoplasm. The visible form changes are confined almost entirely to the enlargement of the nuclear area and the formation of numerous small vacuoles in the cytoplasm. The abnormalities due to the action of phenol are clearly differentiated from those occurring in the distilled water controls as previously described. The sphagnum controls were normal as usual.

THE EFFECT OF STRYCHNIN SULFATE

The preparation of the solution of strychnin sulfate and the manipulation of the material accorded closely with the plan pursued with the phenol. Five strengths of solution were used, which for convenience in comparison are expressed approximately in terms of percentage solutions, viz., 1, 0.5, 0.25, 0.1, and 0.01 per cent. In the first group of experiments the radicles were exposed to the constant action of the several solutions for intervals of 3, 6, and 24 hours. In the second group the root tips were treated with the various dilutions for ten minutes, and were then transferred to distilled water for the time intervals mentioned above. The usual controls were carried in sphagnum and in distilled water.

The 1 per cent solution was allowed to act on radicles for three hours. The tips were then a dull white color and had become flaccid. The cells were all plasmolyzed, and in the outer layers they were disintegrating.

From the external appearance after three hours' immersion in the 0.5 per cent solution death was inferred. However, in plerome and inner periblem a few nuclei were dividing. The outer cells were plasmolyzed and the cell walls were breaking down. In the inner cells the few scattered spireme nuclei and chromatic figures retained their normal shape and orientation in the presence of large vacuoles, one or more of which frequently occurred in the cytoplasm of these cells.

After three hours in the 0.25 per cent solution there were no mitoses.

The cytoplasm of many cells was plasmolyzed, while that of others exhibited a coarse web or net structure, but the cells themselves retained their shape and the outer layers were not disintegrated.

In the tips of radicles acted on by a 0.1 per cent solution for three hours all stages of division were observed. The achromatic figures were very distinct, and nuclei with two nucleoli occurred frequently. After six hours in this concentration the cells of the outer layers were dead and the cell walls had collapsed. There were some spireme nuclei in the inner periblem and a few nuclei were at anaphase. The large deeply staining nucleoli were prominent features of all nuclei not disorganized.

The cells of the outer layers of root tips in 0.01 per cent strychnin for three hours were mostly dead and collapsed. Division figures occurred occasionally in the plerome and were frequent in the inner periblem cells. The spindle fibers of anaphase were clear and distinct, but no polar caps were observed in spireme nuclei. The cell plate was regularly laid down in late anaphase and two nucleoli were frequent in resting nuclei. After five hours in the 0.01 per cent solution some division figures were present. The number of spireme nuclei in proportion to those in the later division stages was greater than at the end of three hours. Very few nuclei were in late anaphase. After 20 hours the area of dead cells included all but those of the inner periblem at some distance from the apex of the tip. No deformation of the nuclei occurred. Even in cells in which the cytoplasm was disorganized, the nuclei frequently retained their normal shape and general appearance. Growth and nuclear activity seemed to have been arrested by the gradual failure of cytoplasmic activity.

The radicles exposed for ten minutes to the strychnin solutions, then transferred to distilled water, were next considered. After ten minutes in 1 per cent solution and three hours in water the cells of the outer layer were dead. In many of the plerome and inner periblem cells containing division figures the cytoplasm was vacuolate, but the figures were not disturbed. All stages of division were observed, but there were no aberrant mitoses.

After six hours in this concentration further disintegration of the outer cells had taken place. Normal division figures persisted in the plerome and inner periblem cells, and a few rare spireme nuclei

showed clearly the polar caps. There were no abnormal structures. At the end of 24 hours there were no mitoses, all the cells were evidently dead.

In the tips exposed for ten minutes to the 0.5 per cent solution, and then placed in distilled water for three hours, mitotic figures occurred even in the outer cells of the periblem. The cytoplasm of these cells usually contained several large vacuoles and the nuclei were all normal in appearance. All stages of normal mitosis were abundant. After 6 hours little change in appearance was visible, but after 24 hours the cells of the outer layers were dead. However, all stages of normal division were abundant in the plerome and inner periblem.

Normal mitoses were abundant in the tips of radicles placed in the 0.25, 0.1, and 0.01 per cent strychnin solution for ten minutes, then in distilled water for 3, 6, and 24 hours. There was no evidence that the strychnin solution had exerted any harmful action in the last three concentrations, during ten minutes' exposure.

The data on the effects of strychnin on higher plants are not very extensive. According to PFEFFER (**25**), it has not been satisfactorily determined that alkaloids affect the protoplasm of plants. In his discussion of the effects of alkaloids in general, CZAPEK (**5**) says: "Für höhere Pflanzen stellte schon Knop an Mais fest, dass Chinin, Cinchonin, Morphin schädlich wirken, und auch hier gehören Chinin, Strychnin, Cocain zu den giftigsten Substanzen, während Morphin relativ schwach einwirkt (Marcacci)." MOSSO (**14**) found that 0.05 per cent solutions of strychnin stimulated germination in *Phaseolus multiflorus*, but that more concentrated solutions retarded it. DAVENPORT (**6**) states that the protoplasm in the tentacles of Drosera is killed by the action of strychnin. He mentions also its retarding action on the germination of peas, corn, and lupines, but unfortunately the concentrations which exerted a harmful action were not given.

The action of alkaloids on Protozoa has been investigated by SCHÜRMAYER (**28**) and others, with results that apparently confirm the theory advanced by LOEW (**13**) that the action of alkaloids is mainly confined to the plasma of the ganglion cells. CLARK (**4**) found that species of fungi, notably Sterigmatocystis, as well as Aspergillus and Oedocephalum, grew and fruited in a saturated solution of strychnin sulfate. CLARK finds that his studies on the molds harmonize with the

theory of LOEW, and concludes that the fungi and bacteria are practically unharmed by this alkaloid, since they have no differentiation of nerve protoplasm. This line of reasoning carried logically forward would argue for the presence of protoplasmic structure in the higher plants which should be comparable with the nerve fibers of animals. Such structures have indeed been described by NEMEC (**19**) from root tips of Allium and *Vicia Faba*. In the latter plant the longitudinal protoplasmic strands of the large plerome cells of the root are regarded by NEMEC as bundles of fibrillae surrounded by a definite sheath and lying imbedded in a special plasma. NEMEC concludes that these fibrils are strands of protoplasm specialized for the conduction of traumatropic, geotropic, and other stimuli, and compares them, although with little apparent warrant, to the nerve fibers of animals. Since the protoplasm often develops a fibrillar structure in connection with other functions, it is not certain that the systems of fibrillae observed by NEMEC are specially adapted for the transmission of these stimuli, and therefore the portion of the protoplasm peculiarly sensitive to the action of alkaloids. ANDREWS (**1**) found that many marine plants, including Cladophora, Ectocarpus, and Polysiphonia, were uninjured by a solution of strychnin sulfate having one part in 1000 of water, but that a solution of the same having one part in 250 killed all the plants in 24 hours.

Although the experiments carried out with strychnin sulfate on *Vicia Faba* were far from satisfactory, they indicate clearly that this reagent is an active poison to the plant used. The cytoplasm first becomes vacuolate, and then degenerates in the outer cell layers, and this condition progresses toward the center of the root tip as the time of exposure to the strychnin solution is extended. It is planned to pursue this line of experimentation farther, in order to determine whether this reagent produces definite and characteristic form changes in the protoplasm.

Summary and conclusions

The cell studies here described were made in the hope of obtaining some further data on the physiology of toxic action. The work which has been done in this direction seems to be concerned more with the production and study of abnormal cell phenomena than with the com-

parison of cell activities under a series of abnormal conditions varying in intensity. It is well known that in a series of dilutions of a toxic substance growth diminishes usually as the concentration increases, and the end sought in these studies was to contrast cell activities under such abnormal conditions of development. No deliberate attempt was made to induce abnormal cell behavior.

The toxic solutions experimented with were (1) copper sulfate, a metallic base which readily ionizes; (2) phenol, a non-electrolyte; and (3) strychnin, an alkaloid presumably poisonous to protoplasm. First the rate of growth of radicles of *Vicia Faba* was determined in a series of concentrations of copper sulfate ranging from $n/20{,}000$ to $n/500{,}000$, then the number of hours required for growth to be reduced to the minimum was next observed in order to determine the range within which to choose material for study. Root tips grown in the above and intervening concentrations were examined at intervals ranging from 1 to 93 hours. Radicles were also subjected to the action of stronger solutions, $n/12$, $n/320$, for intervals of 3 to 10 minutes, and the cells were examined after a lapse of 3 to 30 hours. The results indicate that the toxic effect was first felt in the kinoplasm of dividing cells, as shown by the loss of function and subsequent degeneration of the achromatic figure. Large vacuoles arose in the cytoplasm, frequently deforming achromatic figure and nucleus. Later the entire cytoplasm was disorganized. Development of the chromatic figure was consequently inhibited, but neither amitosis nor abnormal mitosis was observed. In the controls in distilled water, also, the cytoplasm became vacuolate; some of the nuclei were enlarged, and occasionally the formation of the cell plate was interrupted. In both copper sulfate solutions and distilled water the course of events was arrest of mitosis by loss of functions in the achromatic figure, followed by the death and disorganization of the cell contents.

The treatment of root tips with solutions of phenol ranging from $n/188$ to $10/94$ normal produced enlarged achromatic figures and caused the cytoplasm to become very coarsely netted or vacuolate. The chromatic figure was regularly formed and presented no special abnormalities. Neither amitosis nor binucleate cells occurred. The chromosomes were normal in number and structure. Spindle

formation was frequently inhibited, in consequence of which the chromosomes failed to separate normally. With the arrest of mitosis further development apparently ceased.

The experiments with strychnin were unsatisfactory. Solutions ranging from 0.01 to 1 per cent inhibited mitosis and disorganized the cytoplasm, causing the death of the cells. The nuclei were not deformed and the chromatic figures were normal. Strychnin seems to arrest cytoplasmic activity swiftly, without producing visible changes in the mitotic figure.

As a result of their investigations, certain authors state that nuclei can be made to divide amitotically through the influence of toxic solutions. Others, who used the same technic and methods, deny that such solutions produce amitosis, and find that in every case when division occurred the resulting nuclei were formed only by mitosis. BLAZEK (**3**) found that benzol caused the vacuoles in the cytoplasm to increase greatly in size; NEMEC (**18**) observed that chloroform and potassium nitrate produced granulation of the spindle fibers; WASIELEWSKI (**30**) ascribed doubling of the nucleoli to the action of chloral hydrate; WOYCICKI (**34**) states that ether prevented the formation of division walls in dividing cells; and WISSELINGH (**31**) found that under the influence of phenol the cell structures were poorly differentiated.

The authors just cited attributed the above-mentioned abnormalities solely to the action of the toxic substances used. In the experiments described in this paper all these abnormalities were observed in the toxicated material, and also in the controls grown in distilled water. These results appear to indicate that the action of distilled water is a factor which has been overlooked in interpreting the effect of toxic solutions on mitosis, and that numerous abnormalities ascribed to the action of toxic substances are not necessarily so produced.

CONCLUSIONS

1. The practice of growing controls in distilled water, common in certain physiological experiments, is open to serious objections, since these controls are themselves under abnormal conditions, and are subject to the same progressive decline of cell function as occurs in dilute toxic solutions, though at a slower rate.

2. Judged by its effect on mitosis, as compared with the effect of dilute solutions of copper sulfate, *distilled water is itself a toxic solution.* Apparently many abnormalities of cell behavior which have been attributed to the effect of toxic salts may be due instead to the osmotic action of the solution.

3. The achromatic structures organized from the kinoplasm are most sensitive to toxic action. Since the spindle fibers are reduced to a granular mass or otherwise disorganized, the further progress of division is inhibited.

4. Copper sulfate, phenol, and strychnin, under the conditions of these experiments, produce neither amitosis nor truly binucleate cells.

5. No structures occurred in the material studied which the most charitable interpretation could homologize with the large fusion nuclei containing double the normal number of chromosomes, produced, as stated by NEMEC, by a copper sulfate solution acting on radicles of *Vicia Faba.*

6. Doubling of the nucleolus is not a preparatory stage of amitosis, as stated by WASIELEWSKI.

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THE RELATION OF HAIRY AND CUTINIZED COVERINGS TO TRANSPIRATION

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(WITH ONE FIGURE)

Numerous experiments have shown that cutin is a very efficient means of retarding the loss of water from plant tissue. We may cite only such cases as the paring of the apple and its consequent much increased loss of water as shown by weighing, and of various other plant tissues similarly treated. In regard to the function of hairy coverings, however, the lack of experimentation has left us very much in doubt. We find two theories advanced: one holding that such coverings are to retard transpiration, the other that they are to protect the tissue from too intense light. Some have held also that they may, and probably do, serve both purposes, either at the same time or in different cases.

It has long been recognized that hairy coverings must be divided into two classes when function is considered, namely the living and the non-living.[1] The cells of the former contain protoplasm, and therefore are themselves in danger of drying out. Such hairs naturally cannot be used by the plant for restricting loss of water. The non-living hairs, however, are soon free of protoplasmic contents and are filled with air. In such a form, spread out over the plant surface, they may well be conceived of as constituting a restricting screen to the passage of water vapor. By the refraction of light from the contained air this type of hair may also act as a light screen. We shall have to do, therefore, only with this latter group in the following pages.

Experimental evidence for or against either of these theories of the function of air-containing plant hairs is very meager, however, and this is the more remarkable when the very common occurrence

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VOLKENS, G., Die Flora der ägyptisch-arabischen Wüste auf Grundlage anatomisch-physiologischer Forschungen. Berlin. 1887.

of such coverings is considered. In the absence of such evidence the following questions have frequently occurred to the writer: 1. Do such coverings actually retard the loss of water sufficiently to justify their maintenance on this basis through natural selection? 2. Is it not highly improbable that coverings so thin as are "strigose" coverings should affect the loss of water in any way, and does not this count as an objection to the water-retarding theory? 3. If the function of hairs is to retard the loss of water, why should some plants employ thick cutin and others a resinous coating instead of plant hairs to attain the same end? 4. Has the relation to light or the relation to loss of water been the principal factor in the evolution of hairy coverings? Since the answering of these questions has seemed to be of rather fundamental importance in the teaching of ecology, an attempt has been made to obtain evidence, either circumstantial or direct, and the results obtained form the basis of this paper.

The few actual experiments with hairy coverings, so far as I have been able to find, may be summarized as follows. KERNER[2] bound two raspberry leaves around two thermometer bulbs in such a way that in one case the green upper leaf surface and in the other case the white tomentose under surface was outermost. When placed in the sun, the mercury in the green bulb rose to a point 2–5° above that in the white bulb. Two more raspberry leaves were entirely removed from the plant and laid side by side in the sun. The one with the green surface uppermost dried and shriveled much sooner than the one with the white surface uppermost. GOEBELER[3] investigated the effect of trichome structures on the stems of ferns. He found by weighing that the living trichomes markedly increased the transpiration. VESQUE[4] found by means of cultural experiments with certain plants that when the dryness increased, the hairy covering increased in density also. BRENNER[5] found that the hairy

[2] KERNER, A., AND OLIVER, F. W., The natural history of plants **1**:314.

[3] GOEBELER, E., Die Schutzvorrichtungen am Stammscheitel der Farne. Flora **69**:487. 1886.

[4] VESQUE, M. J., ET VIET, M. C., De l'influence du milieu sur la structure anatomique des végétaux. Ann. Sci. Nat. Bot. VI. **12**:176. 1881.

[5] BRENNER, M., see BURGERSTEIN, Die Transpiration der Pflanzen 210. 1904.

covering of certain species of Quercus became thicker when exposed to greater intensity of sunlight.

HABERLANDT[6] selected two nearly equal leaves of the same opposite pair from a plant of *Stachys lanata*. The under side of each was coated with cocoa butter, and from the upper side of one the hair was carefully removed with curved scissors. The two petioles were placed in dishes containing water, and the leaves were left to transpire 24 hours at 20 to 25° C. in the shade. The hairy leaf lost 0.646^{gm} of water and the hairless one 0.915^{gm}, which was therefore in the ratio of 1:1.42. The leaves were then exposed to intermittent sunshine for one hour; the hairy leaf now lost 0.08^{gm} and the hairless one 0.167^{gm}, or in the ratio 1:2.09. He concludes therefore that the hairy covering is especially important in restricting the transpiration in sunlight, but that it also operates in a less degree in diffuse light. In the sunshine it probably prevents the extreme heating of the leaf, in diffuse light it retards the diffusion of the air. The error that might be expected from the exposure of uncutinized surfaces, when the hairs are cross-sectioned, HABERLANDT found by mathematical calculation to be insignificant.

BAUMERT[7] tested the heat screening power of hairy coverings and found that in one case a leaf deprived of hair became 37.5 per cent warmer than a normal one.

It was soon found that to obtain experimental data regarding the effectiveness of various coverings was not easy. In fact, it seems almost impossible to obtain accurate and detailed results because of the many factors that enter. No two leaves are exactly alike in size, or in thickness of cutin, or in water content; and it is very difficult to remove the hairy covering for comparative experiments without injuring the tissue of the leaf. Moreover, the stomates may be open at times and closed at others, and the two leaves used may not be alike in this respect.

Fortunately there seemed to be a method of approaching the problem in an indirect way. It is quite generally recognized that by far

[6] HABERLANDT, G., Physiologische Pflanzenanatomie. 3. Aufl. 116. 1904, and possibly in earlier editions.

[7] BAUMERT, K., Experimentelle Untersuchungen über Lichtschutzeinrichtungen an grünen Blättern. Beitr. Biol. Pflanz. 9:83–162. 1907; and Inaug. Diss. Erlangen. 1907.

the most important factor in transpiration is evaporation; indeed we may say that transpiration is really evaporation modified and regulated by the plant. Therefore, it seemed that a detailed study of the relation of cutin and hairy coverings to evaporation would throw much light on the relation of these same coverings to transpiration.

The first desideratum for such experimental work was a suitable evaporating surface. Several substances were tried, but the choice finally fell on good quality blotting paper. This possessed the desired property of wetting quickly and evenly, and of having a very homogeneous evaporating surface. The pieces used were all cut, for convenience, exactly 7^{cm} square. The plan followed was to expose saturated squares of this paper to the air, each having been previously weighed and then covered with the material to be experimented with. After a given time each was again weighed, and the difference in weight of course represented the quantity of water lost by evaporation. One set of readings in each case was taken in very quiet stagnant air, and another set in air actively in motion. The former condition was obtained by completely inclosing a portion of table top with botanical drying felts placed on edge and covered with the same. For the wind, a small electric fan was stationed at one end of a table on which the evaporating blotters were placed. After a large number of erratic readings were obtained, it was recognized that the following precautions must be taken to eliminate errors. The blotters should be rolled with a round pencil to remove surface water. They should be placed on slightly larger squares of glass and gently rolled again, while with the finger the edges are carefully pressed in contact with the glass. The glass plate and coverings should be weighed with the blotter both before and after. The substance in contact with the blotter should have been previously rendered waterproof in a dilute solution of paraffin in gasoline, otherwise water will be absorbed. The cotton coverings used were always separated from the blotter by a very thin linen cloth so treated. Various materials, in most cases composed of cotton, were used to simulate a hairy covering, but in place of cutin beeswax alone was finally employed. This, while melted, was evenly and thinly spread over the damp blotter with a brush. In order to avoid reducing the supply of water in one case far below that in the other, and thus possibly introducing error,

it was found desirable to conduct the experiments in the wind for only a fraction of the time that they were conducted in still air; but afterward, for comparison, all readings were computed on the basis of quantity lost per hour, and finally on the basis of 1^{gm} lost by the naked blotter per hour. When all the above requirements had been discovered and complied with, a great many readings were obtained in each series, all agreeing within the limits of experimental fluctuation. All the experiments were conducted in the laboratory in February, March, and early April, and therefore in an artificially heated very dry room. The fan was run very rapidly in all cases.

In the following tables the first and fourth columns represent the average quantity in grams lost by each blotter per hour in all the later readings taken. The second and fifth columns show the same quantities reduced to the basis of 1^{gm} for the naked blotter. The retarding effect in the third and sixth columns was obtained by subtracting the loss under cloth, hair, cotton, or wax from the quantity (1^{gm}) lost by the naked blotter. By "increase in efficiency" in the seventh column is meant the number of times greater the retarded effect in wind was compared with the same in still air. The last column represents the number of times this increase in efficiency in wind was greater than the increase in efficiency of wax.

SERIES I.—Coverings used: (*a*) one layer of very thin linen cloth, (*b*) two layers of the same cloth, (*c*) wax coating.

	STILL AIR			WIND				
	Gm per hour	Ratio to 1 gm naked	Retarding, gm	Gm per hour	Ratio to 1 gm naked	Retarding, gm	Increase eff.	Times wax
Naked blotter...	0.398	1.000	.....	4.210	1.000	.....	.....	.....
1 layer cloth....	0.358	0.899	0.101	2.670	0.634	0.365	3.6	2.4
2 layers cloth...	0.338	0.849	0.151	2.110	0.501	0.407	3.3+	2.2
Wax.....	0.181	0.455	0.545	0.780	0.185	0.815	1.5	...

SERIES II.—Coverings: (*a*) one layer thin linen cloth covered with very thin layer of cotton, texture of linen easily seen through the cotton, (*b*) one layer of linen and one layer of thick cotton batting about 2^{cm} thick, (*c*) wax.

Naked blotter...	0.303	1.000	.....	3.310	1.000	.....	....	...
Thin cotton.....	0.262	0.864	0.136	1.430	0.432	0.568	4.17	2.7
Thick cotton....	0.219	0.722	0.278	0.870	0.263	0.737	2.65	1.7
Wax.....	0.153	0.505	0.495	0.740	0.223	0.777	1.55	...

SERIES IIA.—Same coverings as in the last; experiment conducted in sunlight, on a black table top.

Naked blotter...	3.700	1.000	.....	6.820	1.000	.....	....	...
Thin cotton.....	2.590	0.700	0.300	3.320	0.486	0.514	1.71	1.4
Thick cotton....	1.410	0.381	0.619	2.110	0.309	0.691	1.11	0.9
Wax.....	1.220	0.329	0.671	1.350	0.198	0.802	1.19	...

SERIES III.—Coverings: (*a*) one layer of outing flannel (cotton), (*b*) one layer thin ordinary flannel, (*c*) wax.

Naked blotter...	0.343	1.000	.....	3.870	1.000	.....	....	...
Outing flannel ..	0.301	0.877	0.123	1.540	0.398	0.602	4.88	3.37
Ordinary flannel	0.300	0.874	0.126	1.880	0.486	0.514	4.08	2.80
Wax.....	0.157	0.457	0.543	0.810	0.209	0.791	1.45	....

SERIES IV.—Coverings: (*a*) one layer mosquito netting, (*b*) wax.

Naked blotter...	0.340	1.000	.....	3.44	1.000	.....	.....	....
Mosquito netting	0.337	0.991	0.009	2.85	0.828	0.172	19.11	12.7
Wax.....	0.160	0.470	0.530	0.69	0.200	0.800	1.51	....

SERIES V.—Coverings: (*a*) human hair soaked in gasoline and paraffin, cut up into 1–3^{mm} lengths, and sprinkled sparingly over a blotter, to simulate a strigose covering, (*b*) wax.

Naked blotter...	0.3444	1.000	.....	3.58	1.000	.....	....	...
Strigose hair	0.3399	0.987	0.013	3.38	0.944	0.056	4.30	2.9
Wax.....	0.1580	0.459	0.541	0.73	0.204	0.796	1.47	...

From the above five series of readings the following may be deduced:

1. Evaporation from an uncovered surface was about 10.6 or 10.8 times as great in the wind of the fan as in still air (series I and II, columns 1 and 4).

2. In sunshine, under the conditions of the experiment, it was only 1.8 times as great in wind as in still air (series IIA, columns 1 and 4).

3. In still air it was 9.3 to 12.2 times as great in the sunshine as in the shade (series I, II, and IIA, column 1).

4. In the wind it was only 1.6 to 2 times as great in sunshine as in shade (series I, II, and IIA, column 4).

5. Hairy coverings of all kinds and thicknesses used were less efficient in retarding evaporation than the layer of wax employed (columns 3 and 6 in all series).

6. All coverings became more efficient in the wind (column 7 in all series).

7. The efficiency of hairy coverings, in thicknesses at all approaching those actually found on leaves, was very slight in still air (series I, II, and III, column 3, line 2, etc.).

8. Such coverings became very efficient in wind (same series, columns 6 and 7).

9. Their efficiency increased in wind much more rapidly than did that of wax (same series, column 8).

10. Even the layer of cotton 2^{cm} thick did not equal the layer of wax as a protective device. In still air the difference between the two was marked, but in wind became less evident.

11. The thinner coverings showed a greater increase in efficiency over wax than did the thicker (cf. column 8 in series I, II, III, IV, and V).

12. Such thin coverings as strigose hairs and mosquito netting produced scarcely any effect in still air, but showed a marked efficiency in the wind, the increase being 4–20 times, which was 2.9–12.8 times that of wax respectively (series IV and V, columns 7 and 8). Both of these materials may retard in wind as much as 5.6 to 17.4 per cent (series IV and V, column 6).

13. The effect of sunshine was marked. In still air the thin and thick hairy covering became 1.5–1.6 times more efficient when compared with wax. In the wind in sunshine the increase in efficiency was not the sum of the increase due to wind in shade and to sunlight in still air, as one might at first expect, but represented an increase in efficiency over still air in shade that was even somewhat less than the increase in wind shade over still air shade (series II, column 3, series IIA, column 6, and series II, column 7).

14. If hairy coverings on leaves behave in the same way as our artificial hairy coverings, we may say that they produce comparatively little effect in retarding transpiration in still air, but have a marked protective action in wind. Thin strigose coverings produce no appreciable effect in still air, but become important factors in wind. A waxy (i.e., cutinized) covering is more efficient, and has a more constant retarding effect at all times. In sunshine hairy coverings are increasingly protective, their increase in efficiency being

also greater than that of cutin in this respect. Their relative efficiency in wind is not markedly different, whether the sun shines or not (series II and IIA, column 6), being somewhat less perhaps in the former case. Their actual protection, of course, is greater the larger the quantity of water lost, i.e., in wind and in sunlight.

Some experiments were conducted with shellac in the place of the waxy coating on the blotter. The shellac was considered to represent more nearly the resinous coatings so frequently spread over leaves and twigs in dry regions. The readings showed the behavior of waxy and resinous coatings to be very similar.

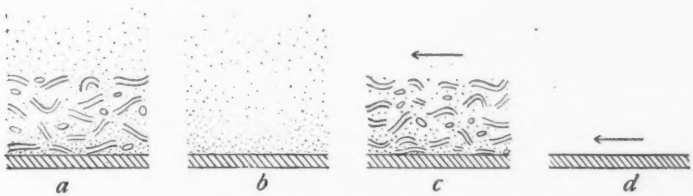

FIG. 1.—Diagrams illustrating the relation of evaporation from naked and hair-covered surfaces in wind and in still air: *a*, hair-covered in still air; *b*, naked in still air; *c*, hair-covered in wind; *d*, naked in wind.

Many readings were taken with actual leaves substituted for the blotters, but in the main they were very erratic. It was found, however, that leaves of Hydrangea and of Nicotiana especially, when covered with layers of cloth and cotton, behaved essentially the same as did the blotting papers. Probably all would have done so if the other factors could have been eliminated.

The reason for the slight efficiency of hairy coverings in still air and their greatly increased efficiency in wind is not at first apparent. The following is the only plausible theory occurring to me. As indicated in the accompanying diagrammatic drawings, in still air a layer of nearly saturated air is soon formed and maintained above the naked as well as above the hair-covered blotter (*fig. 1, a* and *b*). If the hair is thin, it is imbedded in this layer, and the latter is modified little if at all by the hair. Evaporation, therefore, with or without the hair, is into an atmosphere of about equal saturation, and therefore should be about the same. If the hair is very thick, then the

saturated layer of air will be somewhat increased and evaporation will be correspondingly retarded.

In wind, however, molecules are immediately blown away from the naked or wax-covered surface (*d*), while in the hairy covering (*c*) there is retained a partially saturated atmosphere. Air currents do not easily penetrate the interstices between the hairs, and the vapor molecules probably find more difficulty in rapidly passing through the hairs. Since evaporation from a surface is in proportion to the saturation of the adjacent atmosphere, it follows that evaporation in diagrams *a* and *b* will differ but slightly, while between *c* and *d* there will be a much greater difference.

Evaporation is also proportional to temperature. It is reasonable, therefore, to expect an increase when the blotter is exposed to the heat of the sun's rays. Hairy coverings act as a screen to the heat rays, and therefore the cooler blotters beneath them evaporate less. It is probable, however, that the effect of sunshine in nature is rarely if ever as great as in our experiments, except possibly in the case of leaves lying flat on the ground, because of the absorbing effect of the black background of the laboratory tables used.

Significance of the results

We are now able to answer at once the first two questions propounded in the introduction to this paper. A protective action of 35–40 per cent in wind with coverings of the thickness of outing flannel certainly warrants us in saying that hairy coverings are sufficiently efficient in retarding loss of water to justify their maintenance on the basis of natural selection. A protection of 5.6 per cent in wind shows also that strigose coverings may materially affect the loss of water. In the case of strigose plants the hairs are usually developed very early, and therefore while the leaves and shoots are small. The hairy covering is therefore more concentrated and denser at this time, but becomes more scattered as the surface increases. As COVILLE[8] has suggested, such strigose hairs probably function mainly while the organs are young. Hairs which on the mature leaves are scattered far apart may have been of considerable service

[8] COVILLE, F. V., Botany of the Death Valley Expedition. Contr. U.S. Nat. Herb. **4**:53. 1893.

to the young leaf. It now remains to determine what relation the experiments bear to the solution of the last two questions.

From a consideration of the thin unprotected epidermis of hygrophytic plants, guttation through water pores, root pressure, and possibly other methods of increasing the transpiration stream, we may reasonably infer that most if not all plants find it advantageous to maintain as great a transpiration stream at all times as is consistent with their water supply. From this point of view, plants living in a highly desiccating atmosphere may be divided into two groups. In one group the water supply is very limited; in the other, through the presence of water in the soil, the supply is much greater. It would seem highly advantageous, therefore, for plants of the latter group to possess some mechanism by which the transpiration could be retarded when tending to be so excessive as to exceed the water supply, as for instance in strong dry winds or bright sunshine; but which would allow almost uninterrupted transpiration when the transpiration tends to be less, as at night. Plants of the former group would find continued protection desirable. This they would find in the waxy and resinous coatings, while those of the second group would find hairy coverings better adapted to their needs. If our interpretation is correct, we should expect desert plants with very scanty water supply to be highly cutinized, instead of hairy, while the hairy desert plants would be found in some way connected with a greater supply of subterranean water. Such a hairy plant in the desert might be supposed to act as follows. During the day the hot dry winds blow and the sun shining upon the leaflets tends still further to increase the transpiration. The requisite protection is now afforded by the hairy covering; but at night the winds die down, the atmosphere becomes humid, dew falls, and transpiration becomes more difficult. At such times the hairy covering does not materially impede the transpiration.

Known facts do not seem opposed to this interpretation, but rather in its favor. The writer has had no opportunity to determine the available water supply of desert plants, but an inspection of COVILLE'S Death Valley report shows that the habitat of a great majority of the characteristically hairy shrubs cited (p. 52) is given as either dry river bottoms, lake shores, or high on the mountains.

Two densely canescent plants are cited particularly as occurring near timber line on Mt. Whitney (p. 55). Since the mountains according to this report (pp. 22 and 42) are not so arid as are the lowlands, and the soil is generally more moist, all three habitats, therefore, are likely to possess considerable soil moisture. However, to draw generalizations from a report is unsatisfactory, since so much depends on depth of root system, persistence of foliage, etc. Special study of individual conditions in the Death Valley is really necessary.

In the eastern United States, where conditions are mesophytic, hairy plants are found mainly on dry exposed gravelly or sandy knolls and hills, as for example *Verbascum Thapsus*, various species of Antennaria, Gnaphalium, Anaphalis, *Solidago bicolor*, and *S. nemoralis*. Here drying winds and hot sunshine prevail during the day, but at night the air is still and damp. The soil is not excessively dry, but the Verbascum, to still further guard against danger, possesses a long tap root which descends to a considerable depth, where a sufficient supply of water is assured. A hairy covering, therefore, would best meet the needs of such plants.

The most complete account of the occurrence and function of hairy coverings seems to be that given by KERNER.[9] He seems to have believed that the hairy covering so frequently on the under side of the leaf alone could be of functional importance only when bathed with sunlight. To explain this difficulty he showed how when the dry winds blow violently the leaves of the side facing the wind all become inverted, so that the silvery under surface faces the sun. The present experiments show, on the other hand, that the protective action of the hair covering the stomate-bearing surface would be great in wind without sunshine. The inversion of the leaves is not necessary to explain the functioning; indeed, it is doubtful if such inversion continues long enough to be of any great importance. The more important fact is that the hairs cover the stomate-bearing surface rather than the upper surface.

KERNER says that hairy coverings are especially pronounced in the Alps and in the Mediterranean region, but are almost absent from the arctic region. He says that the relation between hairy coverings and transpiration stands out strikingly in those districts

[9] KERNER, A., AND OLIVER, F. W., The natural history of plants 1:313.

where plants during their vegetative period are as a rule exposed to dry air for only a few hours each day, and where their activity is not interrupted by a warm dry period but by frost and cold. On the Alps the complete drying-up of plants by the sun is rare, but the dry winds and hot sun at times make a lessening of the transpiration very desirable. On other mountains of the same latitude in Europe and Asia many hairy plants occur. Indeed, the account given by KERNER is almost an exact picture of what we should expect from the point of view of the present experiments. On the slopes and in the pockets on the Alps, where vegetation exists, the soil is warmed in summer and there is probably an available supply of water throughout the vegetative period.

Quite different is the condition in the arctic regions. Thick evergreen leaves replace the hairy ones. KERNER says: "When hairy coverings are present they are restricted to the under surface, especially to that of rolled leaves. They are never found on plants of rocky slopes, but only on those of damp marshy ground, or by the side of water which is for a short time free from ice." He believes that such coverings are not concerned with transpiration at all, and that the absence of hairy coverings in the arctic regions is due to the moisture in the soil and the consequent absence of danger of drying out. This explanation, however, seems insufficient. If it were true, why should we find thick, highly cutinized, xerophytic leaves on such plants as Diapensia, Empetrum, Vaccinium, etc.? Our explanation now would be that the soil in the arctic regions is too cold for root absorption even in summer, since it remains frozen only a few inches below the surface. The water even if present is therefore not readily available, and there is constant physiological dryness. These are exactly the conditions necessary to demand a cutinized rather than a hairy flora.

Our evergreen leaves, such as those of Rhododendron and Kalmia, are heavily cutinized, not tomentose. According to our theory this would be owing to limited water supply in winter, which is true. Owing to the coldness of the soil and the inactivity of all the living cells of the plant, there is constant physiological dryness.

Plants of the great plains, where the wind is excessive but the ground not extremely dry, are commonly silky, strigose, or tomentose.

Plants of the eastern peat bogs find difficulty in absorbing water, possibly because of toxic substances in the soil, and these are cutinized, not hairy (except Ledum).

KERNER emphasizes the prominence of hairy plants in the Mediterranean region and notes that they are not so numerous in the adjacent steppe region, because "in the steppes and deserts the dryness of the summer is greater, and even thick hairy coverings are not always a sufficient protection against this dryness; and also because in some districts the dry period passes directly into a severe winter." In the Mediterranean region, as the dry summer follows the rains of winter and spring, "their transpiration is very active in consequence of the rapidly increasing temperature of the air, but the saturated soil provides a sufficient substitute for the evaporated water." Toward midsummer, as the drought increases, "if such a plant is to be protected from drying up, its transpiration must be lessened. This is effected by various protective arrangements, but best of all by a thick coating of hair." Very interesting are the biennial plants cited by KERNER. The leaves of these plants formed the first year must pass through the summer and so are abundantly hairy, while those of the leafy flowering shoot the second spring are green instead, because this shoot dies before the summer begins. The whole of KERNER's account of Mediterranean plants is just what we should expect from the standpoint of the present experiments. There is sufficient water in the soil at all times to make moderate transpiration possible even in summer. At times when this supply is at its minimum and when the sun and wind are exceptionally drying, the leaves are protected from too excessive transpiration by the hairy covering.

GOEBEL,[10] in describing the flora on the Venezuelan Andes between tree line and snow line, remarks on the great number of hairy plants. The white-woolly rosettes of certain species are characteristic of the landscape. The climate here is subject to great and frequent changes from rain, snow, or fog, to sunshine and an exceedingly drying wind. The temperature varies also from 0° to 18°. The soil contains plenty of water, with frequent puddles standing on the surface. The soil is cold and absorption is slow, but the transpiration at times

[10] GOEBEL, K., Die Vegetation der venezolanischen Paramos. Pflanzenbiolog. Schilderungen 2:1. 1893.

is great. This is a fine picture of just such conditions as we should expect would demand hairy plants; absorption somewhat below normal, transpiration at times excessive, and at other times, as in foggy weather, very slight.

The use by epiphytic plants of cutin rather than hair for retarding transpiration is well known. Even though the air is humid, the scantiness and uncertainty of the water supply actually obtainable by the plant warrants the employment of cutin. The most notable exception is the Florida moss (*Tillandsia usneoides*), the ecological relations of which I have not been able yet to fully make out. It seems probable, however, that the excessive development of the scaly absorbing glands of the leaves is for still further increasing the efficiency of absorption, rather than primarily to retard transpiration.

Hairs are provided on growing shoots and unfolding leaves to retard the transpiration during windy and sunny times in spring, before the cutin has become fully developed. Some plants make use of resin for this purpose instead (e.g., Larrea in the desert, and Gaylussacia in New England). It is probable that in these cases a more efficient covering is here desired. Such resinous coverings may be superior to cutin in that they may be easily shed or be much interrupted when their early protective action is no longer desired. This actually takes place in both of the above-named examples.

In regard to the last question propounded in the introduction, whether the relation to light or to loss of water has been the principal factor in the evolution of hairy coverings, the following facts may be cited. In practically all cases where one leaf surface is devoid of hairy covering it is the upper. Such cases are very common, e.g., Ledum, Antennaria, Quercus, etc. This would not be true if the primary function was as a light screen. Instead, the covering is maintained over the stomate-bearing surface. The multitude of such cases makes it seem almost obvious that the main function of hairy coverings lies in their relation to transpiration, not to the intensity of the light.

From the foregoing statements it is not to be understood that wherever conditions are as described only hairy plants are to be expected, and that in a given locality plants should be either all

hairy or all cutinized, or even that hairy and smooth individuals of the same species should not be found occasionally side by side. If we go more into the details of distribution than into the consideration of the general trends of vegetation and the general examples already given, we must then consider the individual plants; for it often happens that species growing side by side may in one case have a deep root system reaching ground water, in the other have a root system confined to the driest superficial layers of the soil. It is also conceivable that there may be inherent physiological differences between species, and even between individuals of the same species, calling for variations in the amount and kind of protection. The life economy must be studied out in each individual case. We must not fail to remember, also, that the whole seasonal cycle, as well as the life cycle of the individual, must be considered before a full conclusion may be drawn; for a hairy covering which seems not to fit into the general scheme may have done so at an earlier period of development or in an earlier season.

General conclusions

The evaporation experiments outlined in this paper tend to show that porous coverings like cotton, wool, or hair must be very thick to produce any appreciable effect in retarding evaporation if the surrounding atmosphere is quiet, but become very efficient even in thin layers when the air is in motion. On the other hand, a waxy covering is effective at all times, though of course somewhat more so in wind. In sunshine, also, the hairy covering shows a greater increase in efficiency than does wax.

It seems probable that those plants employ a hairy covering to retard transpiration that live in situations where a moderate water supply is available, but where transpiration must be reduced in excessively dry times, but not interfered with when the surrounding air is damp and transpiration therefore difficult. Cutin, on the other hand, is probably employed when there is considerable danger of too great desiccation at all times.

A contemplation of the general occurrence of excessively hairy plants lends probability to this view.

WELLESLEY COLLEGE

THE MORPHOLOGY OF THE PERIDIAL CELLS IN THE ROESTELIAE[1]

FRANK DUNN KERN

(WITH PLATES XXI AND XXII AND TWO FIGURES)

While making a study of the morphological characters of various species of Roestelia, attention has been especially attracted to the peridial cells. They are much more characteristic than are the roestelial spores, and so strikingly different, except in two known cases, from the peridial cells of the aecia of pucciniaceous species that they are at once conspicuous upon the most cursory examination. The two exceptions just cited are *Aecidium Blasdaleanum* D. & H. and *Aecidium Sorbi* Arth., which are classed with the Roesteliae on account of their life histories, but which have the morphological characters of the pucciniaceous aecia and are therefore not included in the discussions in this paper. The taxonomic importance of the peridial cells in defining the species of Roestelia has been ably pointed out by Dr. ED. FISCHER,[2] and a number of American species have been figured and described[3] in considerable detail by him. FISCHER took into account only the surface sculpturing on the cells, but aside from this there are a number of other features of the morphology which seem worthy of consideration. The microscopical structure is described with some detail in this paper, with the hope that it may be of interest.

The manner in which the individual cells are joined together to make up the peridium is one of the first characteristics worthy of mention. If a bit of the mature peridium of almost any of the species is mounted in water for a microscopical examination, the cells are usually seen separated from one another, or perhaps a few short chains made up of cells attached together at the ends remain. In case the cells do not separate while the mount is being prepared, a

[1] Read before the Botanical Section of the American Association for the Advancement of Science at the Baltimore meeting, December 29, 1908.

[2] Zeit. f. Pflanzenkr. **1**:271. 1891.

[3] Hedwigia **34**:3, 4. *figs. 1–10.* 1895.

slight movement of the cover glass will usually serve to dislodge them. This loose union along the sides of the cells as they are joined to make up the peridial tissue, tends to make the peridium rupture at its maturity by longitudinal slits along the sides rather than at the apex, and gives the lacerated and fimbriated appearance so characteristic of most of the species. Only two species of the true Roestelia type have been observed which have peridia that do not become more or less split up; these are *R. Harknessiana* E. & E., an unattached species from California, and *G. inconspicuum* Kern (*R. Harknessianoides* Kern), from the western mountain region. In these the peridia are firm and remain tubular even after months of weathering.

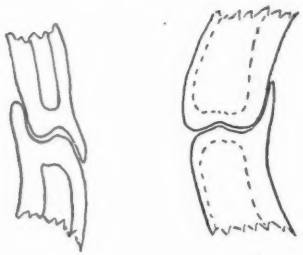

FIG. 1.—Showing how the cells of some species are joined end to end; the portions uppermost are toward the apex of the peridium; in *a* the outer wall of the upper cell overlaps considerably; in *b* this is much less pronounced.

The way in which the cells are joined end to end is another distinctive feature of this group. In addition to being imbricate, a character common to many aecial forms, the ends of the cells are, with a few possible exceptions, articulated in such a manner as to make movable joints (*text fig. 1*). This power of yielding at these joints permits the ruptured peridium to curl and twist in a manner particularly prominent in some of the species.

In shape one finds a considerable variety. In some species the cells are long and thin (*figs. 7, 12*), in others short and very stout (*figs. 8, 15, 16*). With respect to shape, it is necessary to consider the cells from two points of view, viz., side view and face view. The side view, which is the longitudinal radial view, shows the dimensions of length and thickness. In this view the outer and inner walls are practically parallel. In some of the species which have short and rather thick cells, the imbrication at the ends gives an oblique effect which makes a rhomboidal shape (*figs. 15, 16*). Where they are longer and thinner, the length becomes more pronounced, and linear-

rhomboidal (*figs. 3, 4, 10*) is a more accurate description; or where the length is very great comparatively, the obliqueness at the ends is inconspicuous and they may best be described as linear (*fig. 7*). In face view, which is the longitudinal tangential view, length and breadth are the dimensions in the plane of vision. The cell may be regarded as having two faces, the one which is to the outside, and the one which is to the inside as it is in place in the peridial wall. The distance from the outer face to the inner face constitutes the thickness of the cell. In considering shape in face view it makes no difference which face is turned toward us. The cells of some of the species are not easily seen in face view, but of those that will lie so as to be readily examined the majority do not have the side walls parallel, but vary from lanceolate or broadly lanceolate (*fig. 16*) to polygonal-ovate or polygonal-oblong (*fig. 9b*). Most of the cells are more or less narrowed both above and below (*fig. 17b*). There is one species, *G. Botryapites* (Schw.) Kern (*R. Ellisii* Peck), which does not conform to any of the shapes mentioned. It has cylindrical hypha-like cells which are sometimes irregularly bent (*fig. 12*).

The accompanying table will serve to show the variation in size of the cells and in thickness of the walls. In the measurements given an attempt is made to make some allowance for the variation within any particular species, it being the case in most instances that the cells near the apex are proportionately shorter. *G. Bermudianum* (Farl.) Earle, the only autoecious species known to exist, has the shortest cells of any examined (*fig. 1*). The maximum length is three to four times greater than the minimum, and is found in the cells of *R. transformans* Ellis (*fig. 7*), a species developing in the leaves and fruit of *Aronia arbutifolia* (*Pyrus arbutifolia*). In most of the species the breadth is greater than the thickness, but in three or four (nos. 9, 14, 15, 16 in the table) having especially firm peridia, which do not become much split or lacerated, the reverse is the case.

With respect to thickness of walls, the general type of peridial cell has inner and side walls rather thick with outer wall rather thin. The side walls appear to be about equal in thickness with the inner wall in the species where the inner wall is only moderately thickened (*text fig. 2, a, b*). In some very thick and proportionally narrow cells, where the inner wall is excessively thickened, the side walls

are much less and become gradually thinner toward the outer side of the cell (*text fig. 2c*). The outer wall is usually never more than half as thick as the inner and is commonly considerably less. There are two exceptions to the above statements which should be noted here, *G. Botryapites* (Schw.) Kern (no. 12), which has the conditions of

TABLE SHOWING SIZE AND THICKNESS OF WALLS OF PERIDIAL CELLS IN SIXTEEN SPECIES OF ROESTELIA*

SPECIES†	LENGTH (FROM END TO END)	BREADTH (FROM SIDE TO SIDE)	THICKNESS (FROM FACE TO FACE)	THICKNESS OF WALLS	
				Outer wall	Inner and side walls
1. G. Bermudianum	50–75 μ	18–25 μ	15–18 μ	1.5 μ	3–5 μ
2. G. Juniperi-virginianae (*R. pyrata*)	65–100	(16–22)	10–16	2.5–3	4–6
3. G. floriforme	65–85	(14–18)	10–14	1.5–2	4–5
4. G. globosum	60–90	15–23	13.19	1.5	3–5
5. G. Betheli	60–90	20–25	13–20	1–1.5	4–6
6. G. clavariaeforme (*R. lacerata*)	80–130	18–30	15–25	1–2	5–7
7. R. transformans	150–300	(20–30)	12–18	2–3	4–6
8. G. juniperinum (*R. penicillata*)	60–90	(45–55)	30–35	2–3	7–10
9. G. germinale (*R. aurantiaca*)	45–95	19–39	25–40	3–5	13–23
10. G. Nidus-avis (*R. Nidus-avis*)	55–88	15–23	14–18	1–1.5	5–7
11. R. hyalina	87–105	19–29	(20–26)	(12–16)	3–4
12. G. Botryapites (*R. Ellisii*)	145–190	9–14	9–14	1.5–2	1.5–2
13. G. Nelsoni (*R. Nelsoni*)	65–110	18–32	17–27	1–1.5	5.7
14. R. cornuta	60–110	19–29	30–35	2	8–12
15. G. inconspicuum (*R. Harknessianoides*)	65–100	25–35	45–55	5–8	20–35
16. R. Harknessiana	90–112	40–65	58–74	4–6	15–20

*Where the measurements are included within parentheses, it indicates that the cell, owing to some peculiarity in shape or to its hygroscopic properties, does not ordinarily lie in a loose water mount so that this measurement can readily be taken.

†Where the telial connection is known, the species are referred to Gymnosporangium in this table, with the roestelial name, if one exists, included as a synonym.

the general type reversed, a very thick outer wall and rather thin inner wall (*fig. 11a*). The table indicates the variations to be found in a number of species. Not taking into account the exceptions noted above, the thinnest outer wall found was 1 μ, while the thickest was 8 μ. The inner and side walls vary from 3 or 4 μ (*figs. 1, 4*) to 35 μ (*fig. 16*).

The cells of some of the species when examined in loose mounts may be seen easily in either face or side views. When this is the

case the cells lie straight, and there is usually not much disparity between the breadth and thickness (*figs. 1, 10, 13, 14*). There are a number of species, however, in which the cells tend to lie only on their sides when mounted in water, and it is only with difficulty that a face view can be observed. The cause for the cells taking this position is that they become much curved in water (*figs. 2, 5, 6, 7*), and their equilibrium, therefore, is much more stable when they lie on their sides. Such cells are hygroscopic and will straighten out when they become dry. It has been found that the curvature

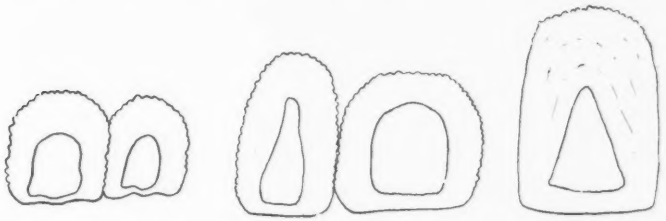

FIG. 2.—Cross-sections of peridial cells of several species: inner walls are above in the drawings; *a*, *G. clavariaeforme* (redrawn from FISCHER), inner and side walls of almost equal thickness; *b*, *R. cornutum*, inner and side walls of about same thickness; *c*, *G. inconspicuum*, inner wall excessively thickened, side walls not so thick, becoming thinner toward outside.

is always inward, the outer wall being on the outer side of the curve. It is interesting to note the effect which this incurving of the individual cells has upon the peridium as a whole. *R. pyrata* (Schw.) Thaxt., the aecial stage of *G. Juniperi-virginianae* Schw., is one of the species which has very marked hygroscopic cells. In the ordinary dried condition of herbarium specimens, the peridium of this species is finely fimbriate and strongly recurved, giving the appearance of having been combed outward. In a saturated atmosphere or in any way under the influence of moisture, the revolute chains of cells may be seen to unroll themselves and take a more or less erect position, or even become somewhat bent inward. They assume their recurved position again upon drying.

With regard to the surfaces of the peridial cells, it has been found that the species so far recognized divide at first into two classes, one

having entirely smooth cells, the other having at least a portion of the surface roughened. I have subdivided the latter class upon the nature of the roughness, and have used the terms rugose, verrucose, verruculose, and spinulose to designate the four subdivisions.

Very little comment is needed for the class having smooth cells. It is the exception to the general rule, only two species being known which belong here. One is *R. hyalina* (*fig. 11*) and the other is *G. Botryapites* (*fig. 12*). These are unusual forms in other ways, as seen by the fact that both have been mentioned previously as being the only forms not conforming to the general type with respect to thickness of walls. Thus it will be seen that nearly all of the species have peridial cells which are sculptured in some way. No single word or even a single phrase will suffice for a description of the markings. It is necessary in most instances to resort to rather long and complicated sentences to convey details enough to be fairly accurate. The terms employed to designate the various classes are intended only to be descriptive in a general way. The rugosely sculptured cells are furnished chiefly with ridges or with elongated ridgelike papillae in such a way that the effect is that of a surface covered with rugae or folds; the verrucosely marked cells are studded with warty or tubercle-like elevations; the verruculose surfaces are covered with low wartlike protuberances; the spinulose cells have diminutive spines or spicules.

The markings always cover the entire inner wall (*figs. 1b, 9b, 17b*), extending to the side walls, in some forms reaching clear across (*figs. 1a, 3, 4, 8, 10, 13, 14, 16*), in others only a part of the distance (*figs. 2, 6, 7, 9a, 15*), leaving the remaining outer part of the side wall and the entire outer wall, with one exception, smooth. Only one species has been found which is an exception to this general type; it differs in having the outer wall also sculptured. This is an undescribed and unattached species (not included in the table), and is further notable in being the only one having cells with spinulose warts (*fig. 17*).

Of the sixteen species enumerated in the table, one-half have rugosely sculptured cells, nos. 1, 2, 3, 4, 5, 8, 10, 14.[4] In all these the ridges or ridgelike markings begin on the inner wall (as in *fig. 1b*),

[4] These numbers also correspond to the figure numbers on the plates.

and are directed downward and outward and extend obliquely on to the side walls. In some species the ridges are of uniform width (*figs. 5, 10, 14*), in others they become somewhat broader toward the outer side (*fig. 2*). In some species the long ridgelike markings are closely and rather evenly arranged (*figs. 3, 10*), while in some they are rather sparsely set with separate and shorter, sometimes roundish papillae in the intervening spaces (*figs. 2, 5, 8*). Nos. 6, 7, 9, 15, and 16[5] have verrucosely roughened cells. The warts vary from roundish or slightly irregular (*figs. 6, 7, 15, 16*) to very irregularly branched forms (*fig. 9*), and are arranged without apparent order. They are usually more sparse toward the outer portion of the side walls. The verrucose character is pronounced in only one form, *G. Nelsoni* Arth., which consequently occupies this class by itself (*fig. 13*).

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EXPLANATION OF PLATES XXI AND XXII

The drawings were outlined with the aid of a camera lucida at a uniform magnification of 625 diameters, and were reduced about one-fifth in reproduction. In every case the end which is uppermost on the plate is the upper end of the cell, or, in other words, the end which is toward the apex of the peridium. In all figures except *11* and *12* the inner wall can readily be distinguished by its relatively greater thickness.

PLATE XXI

FIG. 1.—*G. Bermudianum* Farl.: *a*, side view; *b*, face view.
FIG. 2.—*G. Juniperi-virginianae* Schw. (*R. pyrata* [Schw.] Thaxt.).
FIG. 3.—*G. floriforme* Thaxt.
FIG. 4.—*G. globosum* Farl.
FIG. 5.—*G. Betheli* Kern.
FIG. 6.—*G. clavariaeforme* (Jacq.) DC.
FIG. 7.—*R. transformans* Ellis.
FIG. 8.—*G. juniperinum* L. (*R. pennicillata* [Pers.] Fries.).
FIG. 9.—*G. germinale* (Schw.) Kern (*R. aurantiaca* Peck).

PLATE XXII

FIG. 10.—*G. nidus-avis* Thaxt.
FIG. 11.—*R. hyalina* Cooke: *a*, side view, the thick wall is the outer wall here; *b*, face view.

[5] These numbers also correspond to the figure numbers on the plates.

FIG. 12.—*G. Botryapites* (Schw.) Kern (*R. Ellisii* Peck): the inner wall is the one to the right.

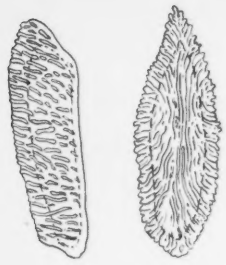
FIG. 13.—*G. Nelsoni* Arth.

FIG. 14.—*R. cornuta* (Pers.) Fries.

FIG. 15.—*G. inconspicuum* Kern (*R. Harknessianoides* Kern).

FIG. 16.—*R. Harknessiana* Ellis & Ev.

FIG. 17.—*Roestelia* sp., an unnamed species, the only one having spinulose markings: *a*, side view; *b*, face view.



1

2

3

4

5

6

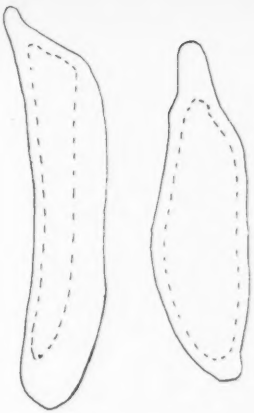
8

7

9

KERN on ROESTELIAE

10



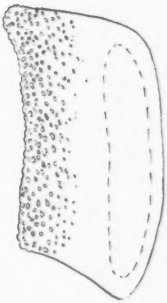
a b

11

12

13

14



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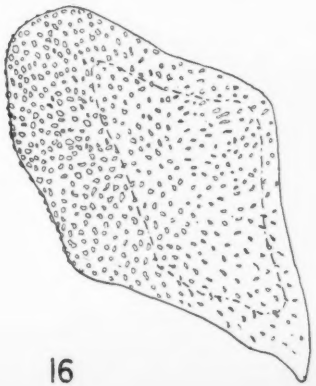

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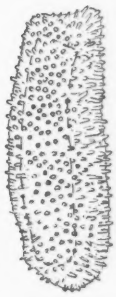
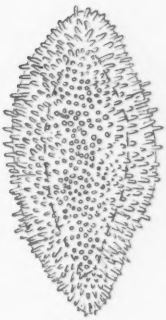


a



b

17

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXXIII[1]

JOHN DONNELL SMITH

Anona (§ATTAE Mart.) **macroprophyllata** Donn. Sm.—Folia subsessilia parva elliptico- vel obovato-oblonga apice rotundata vel saltem obtusa basi rotundata vel retusa. Pedunculi laterales ad basin bracteis binis foliaceis cordato-orbicularibus fulti. Petala exteriora oblonga obtusa, interiora deficientia.

Frutex 3–4-metralis. Folia pergamentacea glabra 4–5.5^{cm} longa 2–3^{cm} lata 7–9-penninervia minutissime reticulata pellucido-punctulata, petiolis 2–3^{mm} longis. Pedunculi glabri 23–27^{mm} longi, bracteis subopppositis primum ferrugineo-sericeis denique praeter basin marginemque ciliatas glabrescentibus, inferiore 20–24^{mm}-diametrali quam altera subdimidio majore, bracteola ad medium pedunculi minuta lanceolata sericea. Sepala ovata 3–4^{mm} longa extus ferrugineo-villosa. Petala extus glabrescentia intus cinereo-velutina 21^{mm} longa 8^{mm} lata basi concava. Stamina 2.5^{mm} longa puberula, filamentis antheras subaequantibus, connectivo ultra loculos pulvinato. Torus staminiferus pilosus. Pistilla 2^{mm} longa. Fructus desideratur.

In praecipite prope Fiscal, Guatemala, alt. 1110^{m}, Jun. 1909, *Charles C. Deam* n. 6191.—Typus in herbario Musei Nationalis servatur.

Krameria (§TETRANDRAE Chod.) **dichrosepala** Donn. Sm.—Cano-sericea. Folia lanceolato-linearia. Pedunculi axillares folia subaequantes supra medium bibracteolati. Sepala 4, duobus intermediis et petalis flavicantibus. Petala superiora sepalis paulo breviora unguibus totis coalita, laminis flabelliformibus. Stamina infra medium unguibus petalorum adnata.

Fruticulus prostratus, ramis virgatis 3–5-decimetralibus cum foliis et pedunculis cano-sericeis hinc illinc rufescentibus. Folia sessilia 7–9^{mm} longa 1–2^{mm} lata in mucronem nigrum 0.5^{mm} longum attenuata basi rotundata margine revoluta. Pedunculi 5–8^{mm} longi, bracteis foliaceis 5–6^{mm} longis. Sepala parum inaequalia 7–8^{mm} longa oblongo-ovata obsolete mucronata extus sericea, extimo valde gibboso et intimo sanguineis, intermediis inaequilateralibus. Petala superiora 6^{mm} longa, laminis 1.5^{mm} longis 2^{mm} latis subcrenulatis, intermedio paulo minore, petalis inferioribus suborbicularibus 2^{mm}-diametralibus subdenticulatis glabris. Stamina 4.5^{mm} longa. Ovarium gibbosum ovale cano-villosum addito

[1] Continued from BOT. GAZETTE **48**:300. 1909.

stylo aequilongo stamina paulo superans. Fructus ignotus.—Ad *K. canescentem* A. Gray et *K. bicolorem* S. Wats. indumento foliis inflorescentia accedens ab utraque inter alia petalis staminibusque connatis recedit.

Ad viam montanam flumen Montagua ultra hand procul a Gualán, Depart. Zacapa, Guatemala, Jun. 1909, *Charles C. Deam* n. 6273.—Typus in herb. Musei Nationalis servatur.

Calliandra (§MACROPHYLLAE Benth.) **rhodocephala** Donn. Sm. —Glabra. Folia breviter petiolata, pinnis unijugis, foliolis trijugis, addito saepius foliolo infimo solitario, inaequilateralibus oblongo- vel ovato-lanceolatis acute acuminatis basi exteriore rotundatis interiore acutis binerviis. Pedunculi axillares et terminales fasciculati breves. Calyx striatus et corolla erubescens.

Frutex 2.5-metralis. Stipulae ramentaceae oblongo-ovatae 8^{mm} longae persistentes. Petiolus communis 1–1.5^{cm} longus, pinnarum rhachi 7–1.05^{cm} longa, foliolis supra praeter nervos puberulos vernicosis in jugo inaequalibus per paria deorsum decrescentibus, terminalibus 10–12^{cm} longis 3.5–4.2^{cm} latis, in pare infimo 3.5–5.5^{cm} longis, foliolo septimo 2–2.5^{cm} longo. Pedunculi circiter 1.5^{cm} longi basi bracteis striatis ovato-lanceolatis 8^{mm} longis medio bracteola minuta muniti, capitulo glabro, juvenili etiam in sicco laete rosaceo, bracteolis floralibus ovalibus 1.5^{mm} longis striatis nigro-apiculatis. Calyx obconicus 3^{mm} longus, lobis rotun- datis 0.5^{mm} longis apice nigris. Corolla 8^{mm} longa supra dimidiam tubulosam infundibuliformis, lobis triangularibus 2^{mm} longis trigono-incrassatis. Stamina rosacea 2.5^{cm} longa, tubo breviter exserto, antheris glanduloso-puberulis. Legumen ignotum.—*C. bolivianae* Britton proxima.

Prope viae ferreae pontem ad Puerto Barrios, Depart. Yzabal, Guatemala, Maj. 1909, *Charles C. Deam* n. 6015.—Typum in herb. Musei Nationalis vidi.

Casearia (§PITUMBA Benth.; Warburg) **nicoyensis** Donn. Sm.— Folia lanceolato-elliptica obtuse acuminata basi acuta serrulata supra glabra subtus glabrescentia, punctis atque lineis obsoletis. Pedicelli fasciculati petiolum subaequantes bracteis majusculis bis longiores flore subbreviores. Calycis segmenta linearia. Stamina 8 glabra breviter connata, filamentis staminodia pilosa paulo superantibus.

Inermis, ramulis novellis stipulis foliorum nascentium tergo pedicellis calyce sordide pubescentibus. Folia coriacea 5.5–8.5^{cm} longa medio 2.5–3^{cm} lata minute appresseque calloso-serrulata erga lucem inspecta pellucido-reticulata, petiolis 3–5^{mm} longis, stipulis lanceolato-ovatis 2^{mm} longis. Bracteae ad nodos foliatos numerosae imbricatae ovatae 2^{mm} longae rufidulo-membranaceae glabrescentes, pedicellis 3.5–4^{mm} longis. Calycis 5^{mm} longi segmenta paene sejuncta 1^{mm} lata obtusa intus glabra. Discus staminiferus 1^{mm} altus, filamentis 2^{mm}

longis, antheris oblongo-ellipsoideis 0.5^{mm} longis nudis, staminodiis 1.5^{mm} longis totis patenter cano-pilosis. Ovarium pubescens ellipsoideum 1.5^{mm} longum in stylum aequilongum indivisum attenuatum, placentis tribus. Capsula deficit.

In fruticetis et secus vias, Peninsula Nicoya, Costa Rica, Apr. 1900, *Adrian Tonduz* n. 13901.

Reynoldsia americana Donn. Sm. Folia ter pinnata, foliolis bijugis cum impare lanceolato-ovatis glandulari-serratis. Umbellae subcapituliformes multiflorae racemosae, racemis fasciculatis pedunculatis, floribus 9–10-meris. Corolla clausa ovato-globosa, petalis oblongis.

Arbor mediocris. Ramuli fistulosi foliorum cicatricibus approximatis notati. Folia juvenilia solum visa petiolo 8–11^{cm} longo computato 27–30^{cm} longa, pinnis primariis 4-jugis, secundariis 3-jugis, foliolis 3.5^{cm} longis 2^{cm} latis, petiolo dilatato-amplexicauli, stipulis obsoletis. Pedunculi circiter 6-fasciculati 2.5–3.5^{cm} longi cum racemi rhachi 1.5–2^{cm} longa crassi, ramis 3–4^{cm} longis plerumque ad apicem rhacheos 5–8-fasciculatis, umbellis subglobosis 22–36-floris, pedicellis teretibus 5–6^{mm} longis inarticulatis, bracteis bracteolisque ovatis parvis, floribus praecocibus ecalyculatis 4^{mm} longis. Calyx hemisphaericus 3^{mm} latus, limbo integro glandulis circiter 6 apiculato. Petala 9–10 calyptratim cohaerentia et sub anthesi dejecta 3.5^{mm} longa 1^{mm} lata apice angustata. Stamina 9–10, filamentis superne inflexis, antheris oblongis 2^{mm} longis. Stigma 9–10-radiatum stylopodio conico impositum. Drupa ignota.—Species hactenus cognitae insularum Oceani Pacifici incolae sunt.

In silvis, Peninsula Nicoya, Costa Rica, Jan. 1900, *Adoljo Tonduz* n. 13823.—Nomen vernaculare *Chile*.—Typus in herb. Musei Nationalis servatur.

Bouvardia Deamii Donn. Sm.—Folia opposita rotundo- vel lanceolato-ovata obtuse acuminata basi rotundata vel acutiuscula. Stipulae integrae deltoideae mucronatae. Pedunculus terminalis 3–5-florus interdum in axilla utraque paenultima uniflorus. Corollae limbus intus cano-velutinus, lobi suborbiculares.

Frutex orgyalis, ramulis divaricatis, novellis sicut stipulae petioli folia nascentia inflorescentia puberulis. Folia supra glabrescentia subtus nervis puberula concoloria 33–38^{mm} longa 15–25^{mm} lata, nervis lateralibus utrinque 3–4, petiolis 1^{mm} longis, stipulis 1.5^{mm} longis. Pedunculus saepius triflorus 2.3^{mm} longus, pedicellis bracteolisque 1.5–2^{mm} longis. Calycis tubus velutinus globosus 1.5–2^{mm}-diametralis lobos subulatos 2–3-plo superans. Corollae tubus cylindricus 9–10^{mm} longus rufescens extus sparsim puberulus intus glaber faucibus staminiferis ampliatus ore constrictus, lobi late patentes 3–3.5^{mm} longi carnulosi intensius coccinei extus glabri. Filamenta tubo ad 2^{mm} infra os breviter adnata, antheris subsessilibus basifixis 2^{mm} longis. Discus glaber. Stylus glaber 4^{mm} longus,

stigmatis bipartiti ramis 1.5^{mm} longis. Placentae ovula involventes. Capsula non adest.

Ad fundum praecipitii prope Fiscal, Guatemala, alt. 1110^{m}, Jun. 1909, *Charles C. Deam* n. 6190.—Typus in herb. Musei Nationalis servatur.

Tonduzia Pittieri Donn. Sm.—Folia 3–4-natim verticillata membranacea lanceolato-elliptica 3–4-plo longiora quam latiora. Calycis segmenta acuta membranacea margine hyalina. Corolla ore canopilosa ceteroquin glabra tubo medio staminifero dilatata. Discus obsoletus. Folliculi divaricati.

Arbuscula 3.5–4.5-metralis omnibus in partibus excepto corollae ore glaberrima. Folia cujusque paris inaequalia 8–12^{cm} longa 3–3.5^{cm} lata utrinque praesertim superne acuminata nitida subtus pallidiora pellucido-nervata et punctulata, superiora ternata, nervis lateralibus sub margine arcuatis, interjecto interdum altero breviore, venis obsoletis, petiolis 6–9^{mm} longis. Cyma pseudoterminalis corymbiformis laxe ramosa resinoso-glandulosa 5–7^{cm} alta 9–10^{cm} lata, bracteolis membranaceis lanceolato-ovatis acutis, pedicellis 3–5^{mm} longis. Calyx 1.5^{mm} longus, segmentis ovatis aegre 1^{mm} longis. Corollae totae 1^{cm} longae segmenta tubum aequantia oblongo-ovalia bis longiora quam latiora apice rotundata tenuiter membrancea venosa. Stamina glabra, antheris subsessilibus. Ovarii carpella semiconnata, stylo basi vix fisso 1^{mm} longo uti stigma 0.5^{mm} longum glabro, ovulis in utraque serie circiter 6. Folliculi 6.5–7^{cm} longi 5^{mm} crassi. Semina ignota.—Hanc ab utraque specie hucusque cognita foliis pro rata latioribus facile dignoscendam claro *H. Pittier*, TONDUZIAE auctori, dicavi.

In praecipite ad Fiscal, Guatemala, alt. 1110^{m}, Jun. 1909, *Charles C. Deam* n. 6098.—In silvis prope Gualán, Depart. Zacapa, Guatemala, alt. 186^{m}, Jun. 1909, *Charles C. Deam* n. 6307.—Typos in herb. Musei Nationalis servatos vidi.

Marsdenia gualanensis Donn. Sm.—Folia utrinque puberula punctata orbiculari-cordata cuspidata 5-nervia. Paniculae axillares sessiles vel breviter pedunculatae petiolum subaequantes inferne bis terve furcatae, ramis suberectis incrassatis, pedicellis gracilibus. Corolla extrorsum glabra, faucibus biseriatim cano-barbatis.

Frutex volubilis 3-metralis, ramis petiolisque glabrescentibus. Folia membranacea in cuspidem 1–1.5^{cm} longam acutam mucrunculatam subabrupte acuminata absque cuspide 6–8^{cm} longa atque lata, sinu rotundato, ima basi cumeata supra glanduloso-maculata, nervis lateralibus praeter basales utrinsecus tribus, venis subtransversalibus, venulis reticulatis pellucidis, petiolis 2.5–3^{cm} longis. Paniculae pubescentes 3–3.5^{cm} longae, ramis bracteosis 12–18^{mm} longis, pedicellis 4–7^{mm} longis. Calyx pubescens 2^{mm} longus, segmentis oblongo-ovatis obtusis, sinubus eglandulosis. Corollae tubus campanulatus lobos obtuse ovatos atque calycem aequans. Coronae squamae oblongo-ellipticae 0.5^{mm} longae gynostegio

dimidio breviores obtusae superne hyalinae. Discus stylinus 0.5^{mm}-diametralis breviter rostellatus. Carpidia glabra ovoidea 0.5^{mm} longa. Folliculi desunt.

In fruticetis ad viam prope Gualán, Depart. Zacapa, Guatemala, alt. 186^{m}, Jun. 1909, *Charles C. Deam* n. 6333.—Specimen typicum in herb. Musei Nationalis servatur.

Heliotropium (§ORTHOSTACHYS A.DC.) **physocalycium** Donn. Sm.—Omnibus fere in partibus glanduliferum. Folia supra scabridiuscula sparsim strigillosa subtus molliter pilosa lanceolato-oblonga transversim venosa. Pedunculi laterales et terminales dichotomi. Calyx fructiferus auctus inflatus. Stylus brevissimus. Fructus oblato-globosus, nucibus dorso exsculpato-reticulatis.

Frutex 3-metralis. Rami petioli pedunculi spicae necnon calyces simul pubescentes et pilis longis patentibus glandularibus conspersi. Folia 8–11.5^{cm} longa 2.5–4^{cm} lata utrinque attenuata, petiolis 8–15^{mm} longis. Pedunculi bis terve dichotomi 5–8^{cm} longi, spicis 7–14^{cm} longis, junioribus scorpioidibus, bracteis bracteolisque obsoletis. Calycis floriferi 3^{mm} longi segmenta lanceolato-ovata herbacea nervosa, fructiferi pentagono-globosi segmenta sibi invicem marginibus applicata late ovata cuspidato-acuminata 4^{mm} longa. Corollae tubus 4–4.5^{mm} longus extus glandulari-puberulus intus glaber ad 1.5^{mm} supra basin staminiferus, lobi semiorbiculares 1^{mm} longi, sinubus nudis. Antherae vix cohaerentes lineari-oblongae 1.5^{mm} longae apice papillosae. Stigma 1^{mm} longum stylo paulo longius, apice truncato-conico glabro. Fructus glandulari-puberulus 1.5^{mm} altus 2^{mm} latus profunde 4-sulcatus, nucibus leviter cohaerentibus, seminibus rectis.

Capetillo, Depart. Zacatepéquez, Guatemala, alt. 1400^{m}, Mart. 1892, *John Donnell Smith* n. 2472 ex Pl. Guat. etc. quas ed. Donn. Sm.—Laguna de Ayarza, Depart. Jalapa, Guatemala, alt. 2400^{m}, Sept. 1892, *Heyde et Lux*, no. 3990 ex Pl. Guat. etc. quas ed. Donn. Sm.—Guatemala, Depart. Guatemala, alt. 1465^{m}, Feb. 1905, *W. A. Kellerman* n. 4559.—El Salvador, 1905, *Cárlos Rénson* n. 258.—(Exemplum utrumque nempe Kellermanianum et Rensonianum in herb. Musei Nationalis vidi.)

Eandem plantam in Ecuador collegit et sub numeris 1443^{a} et 14850 distribuit cl. *Eggers*.

Blechum (§EUBLECHUM Oerst.) **pedunculatum** Donn. Sm.—Folia ovata in petiolum decurrentia. Pedunculi axillares spicam ovoideam subaequantes vel superantes, bracteis obovatis 3–5-nerviis unifloris. Corollae lobi obovati tubo longiores. Capsula tetrasperma, seminibus barbatis.

Fruticulus ascendens 24–30-centimetralis, ramis bifariam pubescentibus. Folia utrinque sparsim bulboso-strigillosa subtus nervis patenter pubescentia 3.5–5^{cm}

longa 2–3^{cm} lata obtuse acuminata ima basi in petiolum totum alatum 1–1.5^{cm} longum abrupte contracta. Pedunculi pubescentes 1–2^{cm} longi, spica 11–17^{mm} longa, axe 6–9^{mm} longo, bracteis circiter 10–16 apice rotundatis basi attenuatis ciliatis 7–11^{mm} longis 4–8^{mm} latis, bracteolis linearibus 1^{mm} longis hyalinis. Calycis segmenta lineari-lanceolata 3^{mm} longa scariosa nervata. Corollae tubus rectus superne angustatus 5^{mm} longus, lobi inaequales, extimus maximus 8^{mm} longus atque latus extus pubescens basi intus aurantiaceus. Stamina summo tubo inserta, antheris subsessilibus. Stylus 3^{mm} longus. Capsula elliptico-oblonga 7^{mm} longa supra medium vacua. Semina pilis rectis glandularibus scabridiusculis munita, retinaculis lanceolato-dilatatis.

Ad viam montanam prope Gualán, Depart. Zacapa, Guatemala, alt. 186^{m}, Jun. 1909, *Charles C. Deam* n. 6277.—Typus in herb. Musei Nationalis servatur.

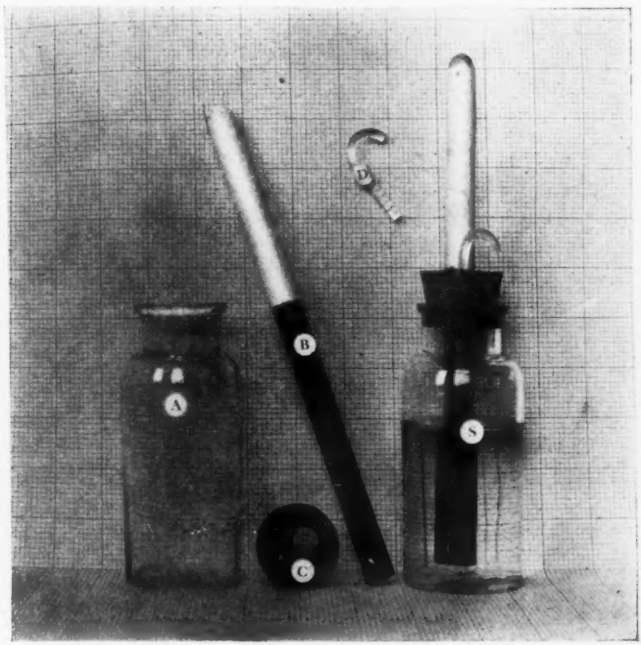
BALTIMORE, MARYLAND

BRIEFER ARTICLES

A SIMPLE VAPORIMETER

(WITH ONE FIGURE)

The accompanying figure shows a simple form of vaporimeter which two years' use has shown to possess some advantages over previously described forms. *A* is a 250^{cc} bottle closed with a rubber stopper (*C*),



through which pass tightly a 25^{cm} hollow porous tube (*B*) and a capillary tube (*D*). The capillary tube permits equalization of pressure without allowing an appreciable evaporation from the bottle except through the porous tube. The use of uniform capillary tubes insures the same sized opening in all of the bottles of a series, prevents the entrance of rainwater,

and has other obvious advantages over the use of loose corks. The lower portion of the porous tube is glazed with DeKotinsky cement to insure a constant evaporating surface. (This cement, by the way, when properly heated is far superior to sealing-wax for most laboratory purposes.) In refilling the bottle or determining the water loss it is only necessary to remove the capillary tube and insert the burette tip. If air bubbles collect in the porous tube when first set up, they may be removed by inverting the instrument and allowing the water to force them out. The collection of air bubbles may be avoided, however, by first placing the tubes in alcohol and then in distilled water, or by boiling in water before setting up. For determining the water loss I found it in some instances advantageous to weigh the entire instrument from time to time. Because of the small size of the porous tube, 250^{cc} of water is sufficient for two weeks of exposure under ordinary Illinois conditions. Under certain circumstances the smaller size is an advantage, because the instrument is less conspicuous.—EDGAR N. TRANSEAU, *Charleston, Illinois.*

PHYLOGENY OF PLANTS

The following statement has been received from Dr. LOTSY in reference to the recent review of the second volume of his *Vorträge über botanische Stammesgeschichte* in this journal:[1]

May I call your attention to an error in your review in saying that "Anthoceros is accorded the status of the most primitive liverwort on the ground that it is nearest the algae in having in each cell only one chloroplast and this furnished with a pyrenoid." Now I certainly do *not* consider Anthoceros as the most primitive liverwort, as I can prove by the following passage on page 74 of my book: "Das primitivste Lebermoos in Bezug auf die Struktur seiner Chromatophoren ist Anthoceros, zu gleicher Zeit das höchste in Bezug auf seine $2x$-Generation. . . . . Ihm und seinen Verwandten ist also eine isolierte Stellung anzuweisen. . . . . Jedenfalls hat Anthoceros eine sehr hoch entwickelte $2x$-Generation und kann uns also bei der Suche nach einer sehr niedrigen Archegoniate nicht behilflich sein. Sehen wir also einmal, ob wir irgendwo anders glücklicher sind." Your deduction that I consider Anthoceros the most primitive liverwort is probably derived from a passage on page 61, which you either understood imperfectly or in which I expressed myself imperfectly. In either case we can both be excused, I think, as you read and I write a foreign language.

[1] BOT. GAZETTE **49**:225. 1910.

I may perhaps be allowed, therefore, to explain in a few words how I tried to get at the "Urform" of the liverworts. I began by saying to myself: liverworts must be derived from an alga-like ancestor, so let us see which liverwort has in its cells the greatest similarity to algae. As such I took Anthoceros, and started to examine it as a possible candidate for the position of the most primitive liverwort, but *rejected* it as such on account of its highly developed $2x$ generation. Having thus failed with Anthoceros, which I had chosen as a possible candidate on account of the cell structure of the x generation, I tried whether I would have better luck in examining Riccia as a candidate, which, on account of its having the most primitive $2x$ generation, seemed to have some qualifications to fill the post of the most primitive liverwort. Unfortunately, I had to reject this candidate also, on account of the high development of its x generation. Having thus found that neither Anthoceros nor Riccia would fill the post, I applied to Sphaerocarpus as the all-round "simplest known" liverwort. In this expression I plead guilty; it would have been better to say "the simplest liverwort now living." This candidate I had to reject also, as its $2x$ generation was already too highly developed, higher in fact than that of Riccia. The "Urform" was therefore evidently extinct, and I concluded that it must have had a very simple thallus, somewhat like that of Sphaerocarpus, and a sporophyte somewhat like that of Riccia; for this reason, I designated this hypothetical form as "Sphaeroriccia." It seems to me that this way of getting at the problem is not so very erratic, but fairly logical; but I regret if I failed to express myself with sufficient clearness; and I am grateful for the opportunity the review gives me to explain my views in this respect in a more satisfactory way.—J. P. Lotsy, *Leiden.*

CURRENT LITERATURE

BOOK REVIEWS

The trees of California

Recent years have witnessed a national awakening to the great importance of forestry, and this in turn has excited a new interest in the trees themselves. People wish to learn something about them, their characteristics, how to distinguish one from another, and their proper names, so that there is an evident demand for books which shall impart this knowledge, not only in a form suited to botanists and technical students, but to any intelligent reader. Too often, however, in the effort to treat a scientific subject in a popular way, the science is so attenuated as to be practically valueless. Fortunately, DR. JEPSON, in supplying California with what is really a popular Sylva of the state,[1] has not fallen into this error. On the contrary, in his keys and descriptions he has adhered strictly to the methods of systematic botany, but so far as possible he has simplified them, and has made no unnecessary use of technical terms.

The first fifty pages are devoted to a number of somewhat detached papers, relating to the characteristics of various tree groups, a consideration of the forest distribution in different parts of the state, and other pertinent topics. A section on "second-growth circles" is of much interest. These circles result, as is well known, from stump sprouts, and the author here considers the extent to which various species of Californian trees possess this valuable regenerative power. The redwood possesses it to a preeminent degree, and the author holds that 80 per cent of the adult trees in a redwood forest originated from stump sprouts, and not from seeds; while some of the circles must have begun their existence more than 1000 years ago.

Of equal interest is the discussion of the relation of periodic fires to the native trees. Such fires are held to have exerted a selective effect on the forest growth, due to the degree of resistance to fire possessed by different trees. In this ability, again, the redwood surpasses all others. For unnumbered centuries it was the custom of the Californian Indians periodically to burn over the country, a habit which appears to have been universal among the aborigines, from the Atlantic to the Pacific. References to it are frequent in the accounts of early settlers and explorers. Perhaps the earliest is that of THOMAS MORTON, in "New English Canaan," published in 1637, where he describes such a custom among the Indians of Massachusetts, and the passage is worth quoting. "The salvages," he writes, "are accustomed to set fire to the country in all places where they come, and to

[1] JEPSON, WILLIS LINN, The trees of California. pp. 228. *photogravures 34. text figs. 91.* San Francisco: Cunningham, Curtis, and Welch. 1910.

burn it twize a year, viz., at the spring, and the fall of the leafe. The reason that mooves them to doe so is because it would otherwise be so overgrowne with underweedes that it would be all a coppice-wood, and the people would not be able in any wise to passe through the country out of a beaten path. This custom hath bin continual from the beginning." Too little account has been taken of the selective effect of such burning, "from the beginning," on the vegetation of our country, and DR. JEPSON has done well in devoting some pages to a consideration of its influence on the trees of California.

The second and larger part of DR. JEPSON'S volume is given to systematic descriptions of the different trees, with the necessary keys for the guidance of the reader to their identification. Both keys and descriptions are satisfactory to the botanist, while not presenting difficulties too great for anyone of fair education and mental ability. The full notes on distribution, economic uses, and cognate topics add much to the interest of the book, whose value is further enhanced by the numerous and excellent figures in the text.—S. B. PARISH.

The trees of Kentucky

There is no more expeditious way to interest people generally in trees and thus promote the conservation of forests than by issuing well-illustrated, non-technical handbooks on the trees of the various states. Thus there is stimulated local pride in the particular trees and forests of any section. One of the neatest and most satisfactory of such handbooks, dealing with the trees of Kentucky, has just appeared.[2] Few states have a more diversified tree flora than Kentucky, which in its eastern portion has a representative development of the Alleghany forests, while in the west there is found a northern extension of the characteristic trees of the Lower Mississippi. The trees are arranged in modern fashion, and there are many excellent photographic reproductions showing leaf, bark, or fruit characters, with a smaller number of full-page plates showing field habits and habitats. The descriptions are particularly good, since the chief distinguishing characters are tersely presented in simple terms, the usual mass of technical description being properly avoided. To the uninitiated it may seem surprising that there are 108 species of trees known to be native to the state (exclusive of Crataegus), while the presence of eight others is suspected; in addition there are ten species of large shrubs that may at times be regarded as trees. The Kentucky Federation of Women's Clubs is to be congratulated on its unusual foresight and good sense in issuing a book of this character and providing for its free distribution within the state; the federation is also to be congratulated for having been able to enlist so capable a person as Mrs. MAURY in the preparation of the volume.—H. C. COWLES.

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[2] MAURY, SARAH WEBB, Native trees of Kentucky, a handbook. pp. 140. *figs.* 47. Louisville: published by the Kentucky Federation of Women's Clubs. 1910. $1.00. (Copies may be obtained from Mrs. H. C. Muir, Nicholasville, Ky.)

MINOR NOTICES

Scientific expedition to New Guinea.—The botanical results, so far as published, of the Dutch scientific expedition to New Guinea in 1907 under the auspices of Dr. H. A. LORENTZ are embodied in the present volume.[3] The groups of plants treated and the specialists who have collaborated in the work are as follows: Filices by H. CHRIST; Palmae by O. BECCARI; Ebenaceae and Loganiaceae by W. P. HIERN; Taxaceae, Sapindaceae, Elaeocarpaceae, Ericaceae, and Gentianaceae by S. H. KOORDERS; Stemonaceae, Burmanniaceae, Corsiaceae, and Orchidaceae by J. J. SMITH; and the Triuridaceae and Polygalaceae by F. A. F. C. WENT. The work is based primarily on the collections made by Dr. G. M. VERSTEEG, collector of the expedition, although plants obtained from other recent expeditions have been included. The treatment of the Orchidaceae occupies by far the greater part of the volume, this family alone being represented by about 60 genera and approximately 240 species. Of these, five species and eleven varieties are described here for the first time, and several are of recent publication. The descriptions of the orchids are supplemented by 46 lithographic plates which beautifully portray the floral characters of more than 150 different species. Of the 73 species of ferns listed, 17 are new to science. The other groups contained in the volume are represented by fewer species, not over 50 in all, but about one-half of these are new. One new genus (*Neojunghuhnia*) of the Ericaceae is described and illustrated. The publication is an important contribution to taxonomic literature.—J. M. GREENMAN.

A memorial volume for Junghuhn.—FRANZ JUNGHUHN was one of the pioneer scientific explorers of Java, and it is very fitting that the centenary of his birth should be celebrated by the publication of a memorial volume,[4] which recalls his many-sided activities and large contributions. JUNGHUHN was born the same year as DARWIN, and after a somewhat stormy youth in his German fatherland, he journeyed to Java, where he remained for many years. Upon his return he became a citizen of the Netherlands, but again returned to Java, occupying a government position there until his death in 1864. The volume contains an account of his life by M. SCHMIDT, and sketches of JUNGHUHN'S contributions to geology, geography, botany, climatology, ethnography, etc., by those best fitted to speak. The botanical sketches are by KOORDERS, who contributes *Plantae Junghuhnianae ineditae, Kritische opmerkingen over de etiketteering van Junghuhn's botanische collecties in 's Rijks Herbarium*, and *Over Junghuhn's verdiensten voor de plantengeographie van Java*. JUNGHUHN is probably best

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[3] Nova Guinea. Résultats de l'expédition scientifique Néerlandaise à la Nouvelle-Guinée en 1907 sous les auspices du Dr. H. A. LORENTZ. Vol. VIII, Botanique. Livraison 1. 4to. pp. 220. *pls. 51*. Leide: E. J. Brill. 1909.

[4] Gedenkboek FRANZ JUNGHUHN 1809–1909. pp. x+361, with portraits of FRANZ and MEVROUW JUNGHUHN, 5 plates, and 48 reproductions of photographs taken by JUNGHUHN. Published by De Junghuhn Commissie. The Hague: Martinus Nijhoff. 1910. *Fl.* 8; geb. *Fl.* 10.

known by his book entitled *Java, seine Gestalt, Pflanzendecke und innere Bauart*, published in 1852, though the first Dutch edition appeared in 1849. The sketches of the Javan vegetation here presented are among the best descriptions of tropical plant life.—HENRY C. COWLES.

Carbohydrates and glucosides.—Another of the monographs on biochemistry, under preparation by English workers, has just appeared.[5] It deals with the monosaccharides, disaccharides, and the more common natural and synthesized glucosides, and forms an invaluable critical consideration of our present knowledge of these physiologically important substances. The seven chapter headings give a good idea of the scope of the work: glucose; the chemical properties of glucose; the hexoses and pentoses; the disaccharides; the relation between configuration and properties; hydrolysis and synthesis; natural and synthetic glucosides. A bibliography of 18 pages adds much to the value of the book.—WILLIAM CROCKER.

Vegetationsbilder.—The island of Juan Fernandez has a vegetation remarkable for the large number of endemic species, which give a peculiar interest to the six plates of KARSTEN AND SCHENCK'S well-known work[6] recently issued as a part of the eighth series. Among the species illustrated are *Boehmeria excelsa*, *Arthropteris altescandens*, *Gunnera peltata*, *Dendroseris pinnata*, and *Robinsonia gayana*. The photographs and brief descriptive text are by CARL SKOTTSBERG. The vegetation of the Swabian Mountains is also shown in six excellent plates after photographs by OTTO FENCHT, who also contributes the descriptive text.—GEO. D. FULLER.

NOTES FOR STUDENTS

Cytology and taxonomy of Endomycetes.—GUILLIERMOND[7] has given an account of his further studies on *Eremascus fertilis*, discovered by Mlle STOPPEL;[8] *Endomyces fibuliger*, discovered by LINDNER;[9] *Saccharomycopsis capsularis*,

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[5] ARMSTRONG, FRANKLAND E., The simple carbohydrates and the glucosides. pp. vii+112. London: Longmans, Green & Co. 1910.

[6] KARSTEN, G., AND SCHENCK, H., Vegetationsbilder. Series VIII. parts 2, 3. Text and *pls. 7–18*. 4to. Jena: Gustav Fischer. 1910. *M* 4 per part.

[7] GUILLIERMOND, M. A., Recherches cytologiques et taxonomiques sur les Endomycétées. Rev. Gén. Bot. **21**:353–391, 401–419. *pls. 12–19*. 1909.

———, Sur la reproduction sexuelle de l'*Endomyces magnusii* Ludwig. Compt. Rend. Acad. Sci. **148**:941. 1909.

———, Quelques remarques sur l'*Eremascus fertilis* Stoppel et sur ses rapports avec l'*Endomyces fibuliger* Lindner. Compt. Rend. Soc. Biol. **66**:925–926. 1909.

[8] STOPPEL, ROSE, *Eremascus fertilis*, nov. spec. Flora **97**:332–346. 1907.

[9] LINDNER, P., *Endomyces fibuliger*, n. sp., ein neuer Gärungspilz und Erzeuger des fol. Kreidekrankheit des Brotes. Wochenschr. f. Brauerei **24**:no. 36.

discovered by SCHIONNING;[10] and *Endomyces magnusii*, discovered by LUDWIG.[11]

Eremascus fertilis is described as having a branched, septate mycelium, the cells of which are two to four-nucleate. The cells which are about to produce the gametes become uninucleate by putting in septa. Isogamous conjugation results from the fusion of the contents of lateral diverticula from adjoining cells. At the point of fusion an eight-spored ascus is formed, in which spore formation is like that in the yeasts. Later parthenogenetic asci are formed, which after the usual nuclear divisions contain four or more spores, some of which may abort. The nuclei of the vegetative cells are so small that their divisions could not be observed. *Endomyces fibuliger* differs from *Eremascus fertilis* in having uninucleate cells, yeastlike conidia which bud off from the cells of the mycelium, and no fusion of the contents of the diverticula. The asci are always parthenogenetically formed in the faster growing protuberance. The author thinks that we have here the remains of an ancestral conjugation absolutely identical with that in *Eremascus fertilis*. *Saccharomycopsis capsularis* differs from *Endomyces fibuliger* in that the cells of the mycelium may become asci or these may bud off from the mycelial cells. *Endomyces magnusii* differs from the preceding forms in having no yeast-like conidia, but the cells of the mycelium readily separate to form oidia. Asci result from the fusion of the contents of uninucleate oogones and antheridia, which are formed at the ends of closely or distantly related hyphae. About one-fourth of the asci arise parthenogenetically. The author holds that this form is related to the Schizosaccharomycetes through its oidia.

According to VAN TIEGHEM'S[12] classification, the family Eremascaceae includes Eremascus, Endomyces, Saccharomyces, Podocapsa, Olinea, Protomyces, Ascoidea, and Dipodascus. GUILLIERMOND would place the last of these genera in a separate group because in these the asci arise as plurinucleate structures and form many (a variable number) spores. He would group the yeasts, Eremascus, and Endomyces together.

DANGEARD[13] thought that the gametes of Eremascus were multinucleate and has placed this genus with Dipodascus, but the author holds that STOPPEL'S work and his own show that Eremascus and Endomyces should be in the same group. The author criticizes ENGLER and PRANTL'S description of Eremascus, and says that it is no longer valid because isogamous conjugation with twisting of gametes is not present in all species. He would retain the genus Eremascus, including *E. fertilis* and *E. albus*, and characterize it by the absence of conidia

[10] SCHIONNING, H., Nouveau genre de la famille des Saccharomycetes. C. R. des traveaux du lab. Carlsberg **6**:93–113. 1903.

[11] LUDWIG, F., Ueber Alkoholgärung und Schleimfluss lebender Bäume. Ber. Deutsch. Bot. Gesell. **4**: Gen. Versammlungs-Heft. XVII–XXVII. 1886.

[12] VAN TIEGHEM, PH., Eléments de botanique. 1908.

[13] DANGEARD, P. A., L'origine du périthèce chez les ascomycètes. Le Botaniste **9** and **10**:1906.

and by the presence of eight-spored asci derived from an isogamous conjugation. According to ENGLER and PRANTL, Olinea also differs from Endomyces in the number of its spores, but this is not an essential character, because in two species of Endomyces there are four to eight spores.

On account of the great resemblance between *Endomyces fibuliger* and *Saccharomyces capsularis*, the latter is placed by the author in the genus Endomyces, which differs from the yeasts in the great differentiation of its mycelium and by having its asci arise almost always from the ends of mycelial branches and not from conidia. The genus Endomyces is characterized by a tendency of the mycelium to form conidia or oidia and by the asci arising from the ends of mycelial branches.

The yeasts are thought to be descended from a form similar to *Eremascus fertilis*. From it there are two main lines, one of which again branches to give rise to Saccharomyces, Zygosaccharomyces, and *Endomyces fibuliger* and *E. capsularis;* while the other main branch gives rise to Schizosaccharomyces, *Endomyces magnusii*, and *E. dicipiens*.—FREDA M. BACHMAN.

Vegetation of the Faeröes.—Several years ago Professor WARMING and his colleagues projected a systematic study of the flora of the Faeröes from various points of view, and there have been published in a special serial devoted to the purpose papers dealing with plant lists of various groups, floristic treatises, and the like. For ecologists the most important paper of the series thus far is one by OSTENFELD[14] on the plant associations and their life conditions, representing a translation of an earlier Danish paper, published in 1906. After reviewing the literature and noting that the best previous account of the vegetation is in ROSTRUP'S work published in 1870, OSTENFELD considers the climatic and edaphic factors in some detail. The climate is decidedly insular, the rainfall and humidity being high and the winter temperature so frequently above 0° that the snow cover is not permanent; the average number of rainless days is 85, while only 18 days per annum are clear. The abundance of sheep is responsible for a high degree of modification in the vegetation covering. In a chapter on the biological features the plants are classified according to their biological type (in the sense of RAUNKIAER), duration of life, type of vegetative propagation, and altitudinal distribution. There are no trees on the islands and there is a striking dominance of perennial herbs; only one autophytic species of the natural land vegetation (*Koenigia islandica*) is an annual. Thirty-six species have never been known to produce viable seeds; this is partly due to climate and partly to the absence of such important pollinating insects as bees and butterflies.

The body of the work deals with the plant formations, which are closely related to one another and separable with difficulty; the author regards this as a feature of an insular climate, which seems reasonable to the reviewer, who has

[14] OSTENFELD, C. H., The land vegetation of the Faeröes, with special reference to the higher plants. Botany of the Faeröes **3**:867–1026. *figs. 31.* 1908.

found similar situations in humid climates generally. The chief categories of natural formations are halophile, subalpine, alpine, and the sea-fowl cliffs, and all but the latter are further subdivided. The halophytic formations are much as elsewhere, and the subalpine formations are mainly those of ponds, swamps, moors, heaths, and cliffs. The cliffs are of much interest, since there is a luxuriant vegetation on sunny southern slopes, while there is a poorer vegetation, mainly of shade mosses, on north slopes. Of rather more interest than usual are the culture formations, the most important of which is the grass meadow. One of the most striking features of the islands is the roof vegetation, which has always been mentioned by travelers; the inhabitants thatch the roofs with grass turf, and very characteristic roof associations develop. The custom of the people is to sow potatoes in cleared ground for two years, after which barley is grown, whereupon the field is left fallow; under the heading "Metamorphic formations," OSTENFELD traces the history of such areas into the grass meadow.—H. C. COWLES.

Some plant diseases.—LANG[15] has given a detailed account of the biology of *Ustilago Tritici* Jens., which, as BREFELD has shown, is peculiar and almost unique among the fungi on account of its habit of infecting the ovule and remaining dormant in the seed until the latter germinates. LANG finds that the spores of this fungus placed upon the stigmas of wheat flowers just opened germinate readily, but the germ tubes show no tendency to penetrate the stylar tissue. Only when the papillae of the stigma have begun to wither and collapse can the germ tubes penetrate between the cells. The fungus apparently has no power of penetrating the sound turgid tissue, a fact which has an interesting bearing in view of the usually strict parasitism of the vegetative phase in this group. The germ tube, without branching, makes its way down the intercellular spaces of the style, or sometimes down the canal formed by the pollen tube, and penetrates the inner integument near the micropylar end, the outer integument having mostly disappeared by that time. When the hyphae reach the chalazal region, they become branched and nodular, apparently showing greater vigor of growth in the region of more abundant nourishment. About three weeks after infection the fungus has reached the embryo. At first it spreads through the scutellum, but later the mycelium pervades every part of the embryo except the radicle. This stage is attained simultaneously with the ripening of the grain. The mycelium remains dormant in the ripe seed, and, when the latter germinates, progressively infects the growing points of the plant, but causes no apparent injury until spores are formed in the ovaries.

GÜSSOW[16] reports the appearance in Newfoundland of a potato disease known as "cauliflower disease" or "potato-canker." The disease is caused by a chytri-

[15] LANG, WILHELM, Die Blüteninfection beim Weizenflugbrand. Centralbl. Bakt. II. **25**:86–101. *pl. 1* (double). *figs. 2.* 1909.

[16] GÜSSOW, H. T., A serious potato disease occurring in Newfoundland. Cent. Exp. Farm, Depart. Agric., Ottawa, Canada. Bull. 63. pp. 8. *pls. 2. fig. 1.* 1909.

diaceous fungus, *Chrysophlyctis endobiotica* Schilberszky. It has been known in Europe for a long time, but has not hitherto been reported as occurring in America. The present article gives a general description of the disease, with figures showing its character. The purpose of the paper is one of warning, to enable farmers in the Dominion to recognize the trouble and prevent its introduction and spread into Canada.

Three fungous diseases of plants, not before reported, are briefly described by OSTERWALDER.[17] He finds that a disease of *Levisticum officinale* Koch., affecting the leaves and stems on which it appears in the form of spots, is caused by a bacterium which is described as *Pseudomonas Levistici*. He was able to produce infections from pure cultures, but only in wounds. A disease of *Calceolaria rugosa* Hort., characterized by rotting of the stems at the ground, is ascribed to *Phytophthora omnivora* DeBary. *Sclerotinia Libertiana* Fuckel is described as attacking *Omphalodes verna* during wet weather.—H. HASSELBRING.

Chemotaxy.—ÅKERMAN[18] studied the chemotactic responses of the sperms of Marchantia by the usual capillary tube method. They react strongly positively to the ions of potassium, rubidium, and caesium (agreeing with the behavior towards proteins as found by LIDFORSS[19]), and weakly to magnesium and ammonium. They are indifferent to sodium and calcium, and react negatively to the ions of hydrogen and zinc and to the bivalent ions of mercury, iron, and copper. In a potassium-free medium the tubes must contain at least 1/1000 mol. KNO_3 in order to attract, while in a potassium-containing medium the tube must have 40 times the concentration of the potassium shown by the medium. The corresponding gradient for proteins is 20. No evidence of osmotaxy was found in the organism. The tactic responses were greatly disturbed by gaseous impurities of the laboratory and by lack of oxygen.

KUSANO[20] has published a full statement of his work in the chemotactic and related reactions of the swarmspores of Myxomycetes. It is characterized by excellence of experimentation, critical consideration, and clear statement of results. *Aethalium septicum*, *Stemonitis fusca*, and *Comantricha longa* were the forms used. It was found that the activity and responses of the spores are not at all affected by a great decrease in oxygen, so the capillary method was used with a cover glass. All acids attract and bases repel; while neutral substances, if of moderate concentration and not highly toxic, act indifferently. Sodium hydrate

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[17] OSTERWALDER, A., Unbekannte Krankheiten an Kulturpflanzen und deren Ursachen. Centralbl. Bakt. II. **25**:260–270. *pls. 2.* 1909.

[18] ÅKERMAN, ÅKE, Ueber die Chemotaxis der Marchantia Spermatozoiden. Zeit. für Bot. **2**:94–103. 1910.

[19] LIDFORSS, B., Ueber die Reizbewegungen der Marchantia Spermatozoiden. Jahrb. Wiss. Bot. **41**:65–87. 1905.

[20] KUSANO, S., Studies on the chemotactic and other related reactions of the swarmspores of Myxomycetes. Jour. Coll. Agr. Imp. Univ. Tokyo **2**:1–83. 1909.

1/1,000,000 mol. repels, while it requires a somewhat stronger solution of hydrochloric acid to attract, and 1/600 mol. of the latter is the optimum for attraction. In acids the attraction is parallel to the dissociability. In high concentrations acids repel, due in strong mineral acids to the excess of hydrogen ions, and in weak organic acids to the undissociated molecules. In many of the latter acids the strong attraction of the hydrogen ion and weak repulsion of the molecule leads to injury and death of the spores because of the toxicity of the latter. The reaction, both negative and positive, is "apobatic" (PFEFFER's terminology) or involves "motor reflex" (JENNINGS). JENNINGS maintains that all tactic responses in animals are of this type, and that PFEFFER's so-called "strophic" reactions do not appear. He thinks it likely also that the same is the case in plants, and KUSANO's work brings more evidence for the support of this probable contention.—WILLIAM CROCKER.

Germination of spores of rusts.—In a paper by SCHAFFNIT[21] some observations and experiments are given which seem to throw some light on the questions relating to the germination of uredospores and aecidiospores of the rusts. The irregularity of germination of these spores is well known to all experimenters, but no satisfactory explanation for their behavior has been given. SCHAFFNIT finds that the capacity for germination depends largely upon the degree of maturity of the spores. By mature spores he understands only those which have fallen from their stalks without being shaken by air currents or rain. Ordinarily large numbers of spores fall from the sori on account of the motion of the infected leaves, caused by the wind. The majority of these spores do not germinate, but if spores are gathered on a hot quiet day, when there is no wind, 80–100 per cent germinate within two hours. The thoroughly ripened spores have a darker color than the immature ones. Spores which have been separated prematurely from their pedicels are incapable of being ripened afterward. It seems, also, that spores cannot be ripened on leaves that have been cut from the plants. These observations suggest an interesting field for further investigation in the ecology of fungi. It must be confessed that our knowledge of the actual behavior, means of distribution, and germination of fungus spores in nature is very meager, even as to fungi of economic importance. Any contribution to this subject is important. The wide application of these results, which the author makes, would hardly seem justifiable until more extended and more accurate experiments have been conducted.—H. HASSELBRING.

Color production in Penicillium.—The effect of external factors on the color production of a certain species of Penicillium has been investigated by DOEBELT.[22] It seems that in agar cultures the pigment, which is red, appears first near the

[21] SCHAFFNIT, ERNST, Biologische Beobachtungen über die Keimfähigkeit und Keimung der Uredo- und Aecidiensporen der Getreideroste. Ann. Myc. **7**:509–523. 1909.

[22] DOEBELT, H., Beiträge zur Kenntnis eines pigmentbildenden Penicilliums. Ann. Myc. **7**:315–338. 1909.

center of the colony. It would seem, therefore, that the pigment formation is the result of catabolic processes in the older parts of the mycelium. A general survey of the paper shows that substances which are favorable to growth, as carbohydrates, also favor the production of pigment; while substances like polyatomic alcohols, which are poor nutrients, result in little color production. It does not seem that the absence or presence of color in these cases can be attributed to any specific action of the compounds, but is rather associated with the general growth of the fungus. The same may be said of the experiments in which pigment production was depressed by withholding necessary mineral nutrients or by high osmotic pressure. A more interesting relation is shown when nitrogen is offered in the form of inorganic salts or as asparagin and peptone. All these substances in the presence of sugar and mineral nutrients favored the production of pigment, but if magnesium sulfate and monopotassium phosphate were withdrawn, color was produced only in the presence of the organic nitrogen compounds. Moreover, in this case abundant pigments were produced in asparagin cultures which gave poor growth. A striking effect on the permeability of the protoplasm was noted when phosphates were absent from the nutrient solutions. In all such cultures the pigment diffused into the culture medium, while in all other cases it remained in the cells.—H. HASSELBRING.

Agricultural experiment station in Palestine.—What is called an American institute of research has been established in Palestine, supported by American capital furnished by several philanthropic Jews. Details of the organization and purpose of this experiment station have been published by FAIRCHILD.[23] It is to be located at the foot of Mt. Carmel, seven miles from Haifa, and will be under the directorship of Mr. AARON AARONSOHN. The director is well known among botanists through his discovery of the long-sought wild prototype of wheat, his personal acquaintanceship having been extended by a recent visit to this country, when he was impressed by the remarkably close agricultural resemblance between California and Palestine. His discoveries of drought-resistant plants, and especially the possibility of using his wild wheat in the more arid regions of the United States, have led to an invitation to prepare a bulletin for the U.S. Bureau of Plant Industry.

The special purpose of the station is to develop rational agriculture in Palestine, but the director has in mind also a wider application of his results, and will issue annual reports in English of the work of the station. It seems that the study of plant pathology is unknown in Palestine, and as a nucleus for such work the collection of the late PROFESSOR W. A. KELLERMAN has been purchased, which the Department of Agriculture has materially supplemented.

The whole movement is one of great interest and promise, not only to Palestine, but to our own country as well.—J. M. C.

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[23] FAIRCHILD, DAVID, An American research institution in Palestine; the Jewish agricultural experiment station at Haifa. Science N.S. **31**:376, 377. 1910.

Effects of carbon monoxid on plants.—SEELÄNDER[24] concludes from numerous experiments that carbon monoxid is to be regarded in general as a plant poison and should be classed as an anaesthetic weaker than chloroform. It exerts injurious effects upon seedlings of *Lupinus albus* and upon germinating spores of *Mucor stolonifer*, *M. Mucedo*, *Penicillium glaucum*, *Aspergillus niger*, and *Botrytis cinerea*. The injurious effect upon seedlings of *Lupinus albus* is shown by an inhibition in rate of growth of the rootlets, which effect is observable with concentrations varying from 75 per cent to 0.5 per cent. Injurious after-effects are to be observed only when the higher concentrations and long exposures are used. Seedlings exposed to the gas show an increased resistance to drying. The spores of the fungi named, germinated on nutrient gelatin in the presence of carbon monoxid, showed delay in germination, and an inhibition in rate of growth of the hyphae, which, especially in the higher concentrations, were irregularly bent and swollen. The minimum concentration necessary to produce the observed results was 1 per cent. The amount of respiration in tubers of *Solanum tuberosum*, bulbs of *Allium Cepa*, petals of roses and dahlias, and swollen seeds of *Pisum sativum* and *Brassica Napus* was little affected by a mixture of 79 per cent carbon monoxid and 21 per cent oxygen. The streaming of the protoplasm in Nitella and in the hairs of various plants, and the ciliary movements of Chlamydomonas and Haematococcus are not affected by several hours' exposure to the gas.—R. C. ROSE.

Permeability.—RUHLAND has already published a paper[25] showing that many dyes highly soluble in lipoids do not enter the protoplasm, while many not soluble in lipoids do. He now offers still more evidence[26] against OVERTON'S lipoid theory of permeability, especially directing attention to the nature of the water solutions formed by the various dyes as shown by the ultramicroscope. He finds that many of the dyes, the water solutions of which are of a colloidal nature, readily enter the protoplasm; methylorange is an example. Others (wollviolletts and erioglaucin), highly soluble in lipoids and forming true solutions in water, do not enter protoplasm.

RUHLAND also offers evidence[27] against the NATHANSOHN and MEURER'S ion permeability hypothesis, which holds that in the exchange of electrolytes between cells and a bathing solution, an electro-chemical balance is maintained. He points out that OSTWALD'S hypothesis, with which this agrees, has long since become untenable from the physical standpoint. He also believes that the large amount of Ca^{++} and Mg^{++} given off in NATHANSOHN'S experiments in

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[24] SEELÄNDER, KARL, Untersuchungen über die Wirkung des Kohlenoxyds auf Pflanzen. Beih. Bot. Centralbl. **24**[1]:357–393. 1909.

[25] Rev. BOT. GAZETTE **47**:342. 1909.

[26] RUHLAND, W., Die Bedeutung der Kolloidalnatur wasseriger Farnstofflosung für ihr Eindringen in lebende Zellen. Ber. Deutsch. Bot. Gesell. **26**:772–782. 1909.

[27] ———, Zur Frage der Ionenpermeabilität. Zeit. für Bot. **1**:747–762. 1909.

balance with the Na^+ and K^+ taken up was due to the toxic conditions of the experiments. He ends by saying that NATHANSOHN's methods are not at all reliable for permeability measurements, and that they cannot be taken as the basis of any explanation of the regulatory permeability of the *Plasmahaut*.—WILLIAM CROCKER.

Fossil woods of Germany.—GOTHAN[28] has described two fossil woods occurring in the brown coals at Senftenberg, from the Lower Miocene. One is a Cupressinoxylon type, *Taxodioxylon sequoianum* Gothan, the structure corresponding to that of *Sequoia sempervirens*. The Cupressinoxylon type of wood in this locality, as in general, is the form most abundantly represented in the brown coals of the Miocene as well as in the Oligocene. The reference of this wood to *Sequoia sempervirens*, or to a closely related species, is in accordance with reports by WEBER, according to whom leaf impressions in beds of similar age at Bonn all belong to *Sequoia Langsdorfii*. The second wood described is that of a new species of pine, *Pinus parryoides*. Although woods of the Abietineae are not nearly so abundant in the brown coals of this horizon as are those of Taxodioxylon structure, they are not rare, and always belong to the group with resin ducts. The epithelium cell walls of the resin ducts of the new pine are provided with pores like those of Picea and Larix, a character not found in any of the recent pines. The question as to its true position is considered at some length, the author arriving at the conclusion that it is the wood of a true Pinus, the character at variance having been lost in recent forms, and that it should be placed in either §PARRYA or §BALFOURIA. Representatives of either of these sections are found only in western North America and eastern Asia.—REINHARDT THIESSEN.

Morphology of Juniperus.—NICHOLS[29] has made a detailed study of the morphology of the American variety (*depressa*) of *Juniperus communis*, obtaining his material from three seasons of collecting near New Haven, Conn. Naturally it is largely confirmatory of the work of NORÉN, SLUDSKY, and Miss OTTLEY, but is especially interesting in its establishment of the time intervals. The staminate strobilus begins to develop during the summer of the year preceding pollination, the mother cells enter into the synapsis stage about May 1, and there is a period of about twelve and one-half months between pollination (May 25) and fertilization. The ovulate strobili begin to appear a few weeks before pollination, the megaspore tetrad is formed late in April, and the female gametophyte develops in about six weeks. The body cell and the central cell divide about three days before fertilization, so that at fusion the egg and sperm are not more than three days old. Some of the more interesting details are as follows: the wall of the microsporangium

[28] GOTHAN, W., Ueber Braunkohlenhölzer des rheinischen Tertaers. Jahrb. König. Preuss. Geol. Landesanstalt **30**:516–532. 1909.

[29] NICHOLS, GEORGE E., A morphological study of *Juniperus communis* var. *depressa*. Beih. Bot. Centralbl. **25**:201–241. *pls. 8–17. figs. 4.* 1910.

is two-layered (overlaid by the epidermis), the inner layer differentiating as the tapetum; the stalk cell is represented only by a nucleus; the two male cells are equal, and occasionally three or four male cells derived from a single body cell were observed; four to ten archegonia are included in the single complex; the fusion nucleus becomes invested by the starch-filled cytoplasm of the male cell; at the first segmentation the male and female chromatin groups are still distinct.—J. M. C.

Respiration.—CZAPEK[30] gives an excellent summary of all work done on respiration of plants up to the present time. It is marked by conciseness and by emphasis on important points. One is surprised that the subject can be treated so thoroughly within the limits of twenty-five pages. The following topics are considered: definition and history, the amount and distribution of aerobic respiration in plants, physical and chemical factors capable of influencing respiration, postmortem carbon dioxid production and oxygen absorption, chemical materials of aerobic respiration, and the mechanism of vital oxidation (statement of our knowledge of respiratory enzymes). The literature considered involves 126 citations.

In discussing the materials used (oxidized) in aerobic respiration, CZAPEK mentions sugars and fats as the principal ones; but emphasizes the fact that in many bacteria (hydrogen, sulfur, nitrifying, etc.) the simplest inorganic substances are oxidized as a source of energy for carrying on life processes, while in many other cases the most complex proteins are split and finally oxidized for the same purpose. It is evident that this gives aerobic respiration a broad meaning. CZAPEK seems very much inclined to distinguish vital oxidations (*vitalen Verbrennungsprozess*) from other oxidations. Vital seems to mean more to him than merely a term to express the unknown.—WILLIAM CROCKER.

The fertile spike of Ophioglossaceae.—The nature of the so-called fertile spike of the Ophioglossaceae has been a prolific cause of discussion, culminating in the divergent views of BOWER and CAMPBELL. CHRYSLER[31] has now attacked the problem from the standpoint of vascular anatomy, examining all the genera, and has reached some important and apparently convincing conclusions.

The fertile spike is regarded as representing two fused leaflets or pinnae (basal pair) of a fern leaf. The proof is most obvious in *Botrychium virginianum*, in which each one of the pair of vascular bundles that supply the fertile spike leaves a gap in the trough-shaped leaf trace. This is sometimes less distinct in *B. ternatum* and *B. obliquum*, and certain other species show no trace of the gap; all of which are taken as indications of reduction. Abnormal specimens also confirm the view. The condition in Ophioglossum is considered to be derived

[30] CZAPEK, FR., Die Atmung der Pflanzen. Ergebnisse der Physiologie **9**:587–613. 1910.

[31] CHRYSLER, M. A., The nature of the fertile spike in the Ophioglossaceae. Annals of Botany **24**:1–18. *pls. 1, 2. figs. 16.* 1910.

from that found in Botrychium; while in Helminthostachys the fertile spike is interpreted as representing a single pinna. This would dispose of the sporangiophore nature of the spike, and revert to ROEPER's view (in 1826) that it represents two fused basal pinnae.

The general conclusion is that the Ophioglossaceae are related to the ferns, and "have sprung from near the level of the Osmundaceae."—J. M. C.

The strobilus of Selaginella.—Miss GERTRUDE MITCHELL[32] has recorded some general studies of the strobilus of Selaginella, which fill up certain gaps in our knowledge, and "confirm or controvert statements" of other investigators.

In some species the axis was observed to renew its ordinary vegetative character beyond the strobilus: in one case abortive sporangia were produced in the axils of the foliage leaves just beyond the tip of the strobilus; in another species a second strobilus was produced upon such an axis, the two strobili being separated by a sterile region; and in still another case a branched strobilus was noted. The distribution of sporangia is variable, and species are enumerated under the following heads; one large basal megasporangium, several basal megasporangia succeeded by microsporangia, strobili wholly megasporangiate or microsporangiate, and an indiscriminate arrangement. The species are also enumerated that mature one, two, or three megaspores, instead of the more usual four, and also two rare cases in which there are twelve (*S. Vogelii*) and eight (*S. involvens*) megaspores. Considerable attention is given to the sporangium wall and its mechanism for dehiscence, involving what are spoken of as "its wonderful adaptations for cross-fertilization." The paper closes with a brief consideration of the vascular anatomy of the strobilus and the ligule.—J. M. C.

The stele of Osmunda.—The vascular anatomy of this genus has given rise to much discussion and to divergent opinions as to its phylogenetic significance. FAULL[33] has now investigated abundant material of the sporelings of *O. cinnamomea* in all stages, and has reached the following results and conclusions: The cortical cells at the base of the sporeling are inhabited by a fungus. While there is considerable variation in the development of different individuals, in no case is the transition from protostele to siphonostele effected by a simple expansion, as has been claimed for Osmundaceae. There are bays or gaps in the xylem near the nodes, which may result in inclosing a "stelar" pith. Rarely and only in adult stems does the internal endodermis and "extrastelar" pith connect with the external endodermis and cortex through leaf gaps. Internal phloem has been found in unbranched adult plants, and this fact, together with the absence of branching in the sporeling, is thought to indicate that internal phloem and

[32] MITCHELL, GERTRUDE, Contributions towards a knowledge of the anatomy of the genus *Selaginella* Spr. Part V. The strobilus. Annals of Botany **24**:19–34. *pls. 3, 4.* 1910.

[33] FAULL, J. H., The stele of *Osmunda cinnamomea*. Trans. Canadian Inst. **8**:515–534. *pls. 4–6.* 1909.

internal endodermis in this family have not "intruded" through branch gaps. The general conclusion is that the stele of the existing Osmundaceae is a "reduced amphiphloic siphonostele," and that it is consistent with JEFFREY'S theory of the origin of the siphonostele and the homology of the pith.—J. M. C.

Morphology of Laminaria.—A knowledge of the reproduction of Laminaria has long been a desideratum, and this has now been supplied to some extent by DREW,[34] who has succeeded in making cultures according to methods he describes. He has concluded that the "sporangia" described as imbedded in the reproductive areas are in reality gametangia. These gametangia produce gametes (heretofore thought to be zoospores) which conjugate and produce zygospores. The zygospores give rise to a chain or mass of cells which may represent the $2x$ generation; and this in turn gives rise to the Laminaria plant, which represents the x generation. The x and $2x$ conditions are inferences, as no cytological work was done; and the direct outgrowth of the young Laminaria plants from the "chain or mass of cells" would hardly suggest an intervening reduction division. However, the discovery that the reproductive areas consist of gametangia and paraphyses is of sufficient interest. The gametes when liberated seem to have no cilia, but soon develop them. The cells of the structure (chain or mass) produced by the zygospore "rupture, and their contents grow out to form the gametophyte." Details are given of the development of the various regions and tissues of the young plant.—J. M. C.

The ecology of Zostera.—OSTENFELD has given an interesting ecological account of *Zostera marina*, as seen in Denmark.[35] The structure and growth of the plant is first treated in detail, following which is an account of the necessary life conditions of the plant and the variations in diverse habitats. While Zostera requires salinity, it thrives where the percentage of salt is high (3.3 per cent), and also where it is very low (0.6 per cent). It occurs only in relatively quiet waters, and grows at greater depths in clear than in muddy waters, sometimes living at as great a depth as 11^m where the water is very transparent. The most important factor in determining its luxuriance appears to be the character of the bottom, plants on firm sand having short narrow leaves, whereas plants in mud have long broad leaves (sometimes more than 2^m in length). A detailed account of the distribution of Zostera in Danish waters is followed by a discussion of the Zostera vegetation as a habitat; many plants and animals live where a Zostera vegetation has become established, the plants themselves often being covered with many forms. Other flowering plants that grow with Zostera are briefly described.—H. C. COWLES.

[34] DREW, G. HAROLD, The reproduction and early development of *Laminaria digitata* and *Laminaria saccharina*. Annals of Botany **24**:177–190. *pls. 14, 15*. 1910.

[35] OSTENFELD, C. H., On the ecology and distribution of the grass-wrack (*Zostera marina*) in Danish waters. From Report Danish Biological Station. pp. 62. *figs. 9*. Copenhagen. 1908.

Seedlings of Cactaceae.—Among the Cactaceae certain members, including the genus Pereskia, have a seedling with two fairly thin cotyledons and a slender hypocotyl; while others, as Mamillaria, have minute cotyledons and a globular hypocotyl. Miss DEFRAINE[36] finds that the mode of transition from stem structure to root structure in these two groups is different; in other words, the adaptations to environment shown by the adult plants has spread to the seedlings, and has also had an effect on the internal structure. Since some species show a pair of bundles in the hypocotyl, a comparison is instituted with the liliaceous genus Anemarrhena, in which the same condition appears. The presence of the double bundle in the cotyledon of this genus has been used by Miss SARGANT as the basis of her argument for the derivation of monocotyledons from dicotyledons by fusion of the two cotyledons, but Miss DEFRAINE finds the origin of the double strand in the Cactaceae so various that she considers the validity of the argument to be seriously weakened. A number of interesting points of detail are recorded in the paper, supplementing the work of GANONG[37] on the cactus family. —M. A. CHRYSLER.

Foliar gaps of Osmundaceae.—JEFFREY'S Pteropsida are characterized by the presence of leaf gaps, but it has been urged by some recent investigators (notably KIDSTON and GWYNNE-VAUGHAN) that they are absent frequently in the Osmundaceae. SINNOTT[38] has undertaken to investigate this group, and concludes that leaf gaps are always present. In the six living species studied a number of cases of mature stems were observed in which the gap did not become complete for some time after the departure of the leaf trace, "which thus at first seemed to go off in a gapless manner." All of the known fossil Osmundaceae with true parenchymatous pith show leaf gaps, with one exception, and this is explained as "a form with very short and narrow gaps, which have been largely obliterated in the process of fossilization." In all the young plants investigated, leaf gaps were evident from the earliest stages. Putting together the testimony from fossil and living forms, and also the juvenile and mature stages of the latter, the conclusion is reached that the presence of leaf gaps is a primitive feature of the Osmundaceae, and that they are placed properly among the Pteropsida.—J. M. C.

Embryo of Pinus Pinaster.—SAXTON[39] has studied the development of the embryo of this species as it grows in Cape Colony. The general results are as

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[36] DEFRAINE, E., The seedling structure of certain Cactaceae. Annals of Botany **24**:125–175. 1910.

[37] GANONG, W. F., Contributions to a knowledge of the morphology and ecology of the Cactaceae. Annals of Botany **12**:423–472. *pl. 26.* 1898.

[38] SINNOTT, EDMUND W., Foliar gaps in the Osmundaceae. Annals of Botany **24**:107–118. *pls. 11, 12.* 1910.

[39] SAXTON, W. T., The development of the embryo in *Pinus Pinaster* Soland., with some notes on the life history of the species in Cape Colony. S. African Jour. Sci. **6**:52–59. *pl. 2.* 1909.

follows: the embryo does not penetrate the endosperm mechanically, by means of the elongating suspensor, but probably by the secretion of an enzyme; it grows for a time by means of a true apical cell, which later is replaced by a group of initials; after this, the most active growth is at the proximal end of the embryo, the first differentiation being the root periblem, the cotyledons and stem tip appearing later. It is an interesting fact that the species produces only two archegonia.

The seasonal differences between Cape Colony and the northern hemisphere in reference to the development of structures are very interesting. Pollination occurs during the winter; the ovule is in the resting stage during the late summer and autumn; pollination and fertilization are separated by 14–15 months (12–13 in England, etc.); the archegonia mature more slowly, the central cell persisting for at least three weeks (as compared with one or two weeks).—J. M. C.

Capsella Bursa-pastoris and C. Heegeri.—The relation of *Capsella Heegeri*, discovered growing wild in Germany ten years ago, to the cosmopolitan *C. Bursa-pastoris* has been in question. Its appearance in a region whose plants are so well known suggested its recent origin by mutation, and in that case the parent plant should be *C. Bursa-pastoris*. SHULL[40] conducted a series of cultures and reported the results at the Boston Meeting of the International Zoological Congress in 1907, and the report has just now appeared as an advance print from the Proceedings! The matter is old, but this publication of it may be noted. The results showed that *C. Heegeri* has the same Mendelian units in its leaves as occur in *C. Bursa-pastoris;* that the crossing of the two species gives rise to corresponding series of elementary species; that leaf characters are inherited in strict Mendelian ratios, but the capsule shows a very great departure; and that the capacity of *C. Heegeri* for self-maintenance in competition with *C. Bursa-pastoris* rests upon the comparative infrequency of cross-fertilization.—J. M. C.

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[40] SHULL, GEORGE H., Results of crossing of *Bursa bursa-pastoris* and *Bursa Heegeri*. Advance print from Proc. 7th Internat. Zool. Congress. pp. 6. 1910.

GENERAL INDEX

Classified entries will be found under Contributors and Reviews. New names and names of new genera, species, and varieties are printed in **bold face** type; synonyms in *italic*.

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